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EUROPEAN
INFORMATION TECHNOLOGY

A Report on the Industry
and the State of the Art

pacing the progress of information technology

AUERBACH
Electronics Corporation

philadelphia
and new york

Technical Report
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EUROPEAN INFORMATION TECHNOLOGY

A Report On The Industry And The State Of The Art

Submitted to

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Office of Naval Research
Washington, D.C.

By

AUERBACH Electronics Corporation
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I-INTRODUCTION

In a mere fifteen years the electronic digital computer has risen from a laboratory curiosity to a vital element of present-day civilization. The phenomenal growth of the computer industry in the United States has been the subject of many articles, both technical and popular. But too little attention has been given to the work going on in other countries. Indeed some very basic research and development is being conducted outside the United States, proving that there are no boundaries or limitations to the conception of ideas. It is therefore of inestimable value to keep in focus these activities and recognize the magnitude of the ever-growing world market.

While virtually every nation today is engaged in some sort of computer activity, the most significant work being done outside the United States is found in Western Europe. Here several countries, notably Great Britain, France, Sweden, The Netherlands and Germany have been active for many years and have well established research groups and manufacturing concerns. Other nations entered the field more recently, but are aggressively forging ahead in basic research and product development.

In an effort to learn first-hand just what the Europeans are doing in information processing, the author spent seven weeks touring the continent and Great Britain, visiting every major area of computer activity.

Through exhaustive interviews, tours of facilities, and examination of equipment, it was possible to assemble this presentation of the technical state-of-the-art in Western Europe.

The survey of European activities is presented in four parts: an introduction; details of some important technological developments under way; a description of the current activities of each organization visited, including details of computers and other products; and a series of charts comparing the characteristics of European computer systems. The technological developments include fixed high-speed memories, magnetic thin films, random-access memories, pattern recognition, learning machines, hydraulic logic, and problem-oriented languages.

II-TECHNOLOGICAL DEVELOPMENTS

All over Western Europe important research is being conducted by both commercial and government organizations in advancing the state of the computer art. Some of the work parallels that being done in the United States and elsewhere, while in other cases European groups are pursuing entirely new ideas. Although not all advanced developments are revealed to an outside observer, the author was fortunate in seeing much original and interesting work in process. The items of particular interest are noted below, categorized by technical subject matter so that the result of several organizations working in the same area may be grouped together.

FIXED HIGH-SPEED MEMORIES

There is interesting development work in Western Europe in the area of fixed high-speed memories, including both technique developments and application studies. Two techniques receiving particular attention are wired-core memories and fixed memories using magnetic rods.

Wired-Core Memories

Wired-core memory techniques, well known but little used in the United States, are extremely popular in Western Europe. Almost every modern European computer uses some form of wired-core storage.

In wired-core storage, a wire is threaded through a core matrix in a pattern which represents the stored information. Such memories are

characterized by non-destructive readout, with higher speed (under one microsecond switching time is typical) and lower cost than coincident-current memories. Wired-core memories are used to store various fixed or seldom-changed data; e.g., start-up sequences, basic programs for communicating with peripheral equipment, basic subroutines such as standard trigonometric functions, program constants, and, in some cases, entire operating programs. The technique is particularly useful in microprogramming, where the cores control logical gates and the structure of the wired-core matrix defines the logical characteristics of the computer. Industrial control is one of the areas where wired-core techniques have great potential application.

Telefunken (Germany) uses E-shaped wire cores in the TR-4, a large-scale, high-speed, solid-state computer. One slot of the E-core stores a ONE and the other slot stores a ZERO. A storage capacity of 256 words is achieved with 52 cores and 52 diodes mounted on a single plug-in card threaded with 256 wires. Telefunken claims an access time of one microsecond, with a 30 percent cost saving over coincident-current systems.

N.V. Electrologica (Holland) uses wired-core storage in the X-1 computer. Organized in blocks of 64 words, the storage is used for peripheral equipment subroutines. N.V. Electrologica has automated the assembly of the wired-core matrices with punched paper tape.

Most other European groups are active in wired-core development and application, particularly Elliott Brothers in England, who have used the technique for serial and parallel storage in process-control computers.

Fixed Rod Memories

The advantages of wired-core memories are retained and the disadvantage of inflexibility of modification is overcome in a new memory system developed at the University of Manchester in England. Using small magnetic rods inserted in a wire mesh, this 8192-word memory has achieved the highest operating speed of any known memory of equal size being built into a computer anywhere in the world. Cycle and access times of 0.3 and 0.15 microseconds, respectively, have been achieved in laboratory tests.

The fixed rod memory, developed by Professor Thomas Kilburn for use in the radically new MUSE computer under development at Manchester, has a capacity of 8192 48-bit words. A smaller version, with a 256 x 256-bit capacity was built at the University of Pisa in Italy for the C.E.P. computer, using parts supplied by Manchester.

The fixed rod memory is constructed from a woven mesh of copper wire mounted over a soft plastic. Ferrite rods one millimeter in diameter and 5 millimeters long are placed in the interstices of the mesh wherever a ONE is to be stored. The woven mesh for a 4096-word memory is three feet wide and eight feet long, with 1/16-inch grid spacing. The mesh, folded in half over the plastic, results in a two-sided frame three by four feet. There are 256 x 768 loops in the mesh, organized as 256 x 16 words of 48 bits each.

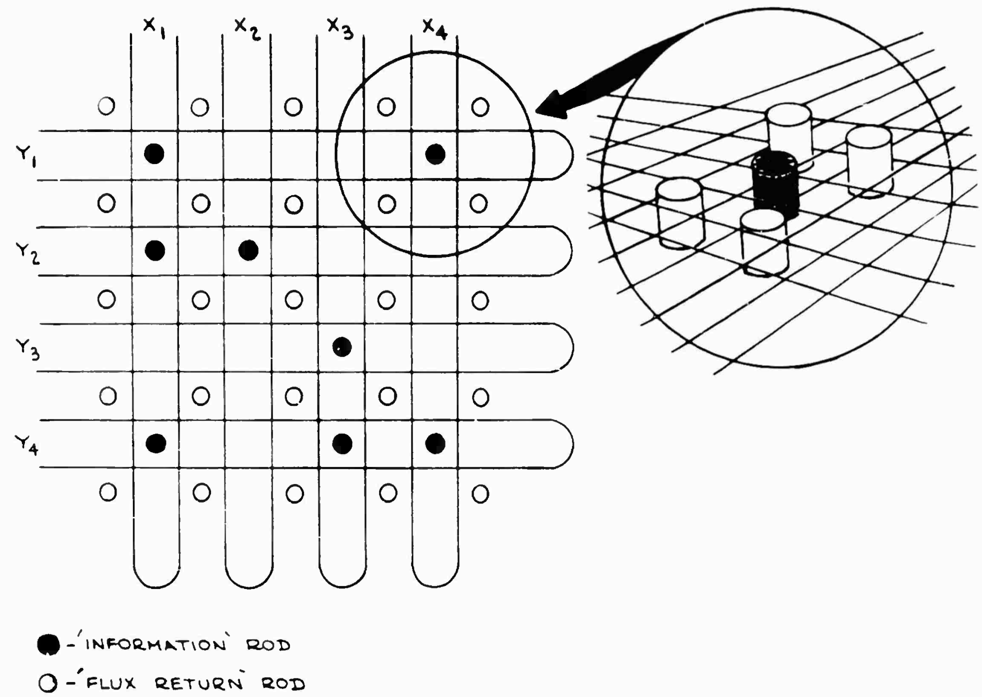

Figure 1. Kilburn Fixed Rod Memory Technique

The wire mesh is formed into loops (see figure 1) by cutting one horizontal and one vertical edge of the mesh. When a ferrite rod is inserted within both a horizontal and vertical loop, it couples these loops and may be detected. To provide a flux return path for the magnetic field and to reduce noise, identical rods are inserted in all of the non-coupled loops.

The memory is organized by switching 48 sense amplifiers to a selected 1-out-of-16 group of 48 loops on the vertical axis. A single driver switched to one of the 256 loops on the horizontal axis provides the interrogation.

MAGNETIC THIN FILMS

Research on magnetic thin films is underway in many laboratories throughout Europe. Two of the organizations visited - IBM Zurich and ICT in England - made some information available about their programs so that a brief review of these programs serves as an indication of the state of the art.

At the IBM Laboratories in Zurich a major program on magnetic thin films is divided between two groups: one engaged in metallurgical methods for depositing and heat-treating ferro-magnetic films, and the other concerned with the switching properties of the films and their application in logical devices and memory.

IBM's investigations show that the ferromagnetic resonance of a thin film occurs at one kilomegacycle, which may establish the upper boundary for speed. The possibility of making use of the ferromagnetic resonance in new circuits is being studied. Experiments have been conducted on nanosecond switching of film 1000 angstroms thick and 1 centimeter square. Output signals of up to 0.1 volt have been obtained, comparable to signal amplitudes derived from small ferrite cores. Memory planes are being tested.

Through microscopic examination of the thin film under polarized light, both the IBM and ICT researchers have been able to observe the domain-wall switching and have discovered that the domains "lock up" on impurities.

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In England, International Computers and Tabulators Ltd. is active in thin-film research. ICT's main emphasis is on improving the reproducibility of the desirable properties of the magnetic thin film, to permit economical manufacture of large-scale memories with cycle times under 100 nanoseconds. Metallurgical research at ICT has produced a new alloy, called Gyralloy, which is deposited by vacuum evaporation onto an oxidized aluminum substrate. The presence of a conductor so near the film gives a good signal-to-noise ratio and reduces the drive impedance, because magnetic flux cannot penetrate into the conductor in the duration of the selection pulse. ICT claims no harmful damping effect on the magnetic reversal with this arrangement.

An experimental thin-film memory assembly built by ICT is shown in figure 2. The Gyralloy is deposited on the aluminum substrate in a continuous film, rather than in spots, as is done elsewhere. An insulating layer is applied over the film; over this are printed-circuit copper conductors, which form the read winding. At right angles to the read winding are coils of flat wire, with ten turns per coil: again at right angles to these coils is a set of conductors embedded in a plastic sheet, for x/y control.

Other European groups engaged in thin-film research include Siemens & Halske and the Max Planck Institute fuer Physik in Germany, and Plessey, Mullard, Radio Research Laboratory and the University of Manchester in England.

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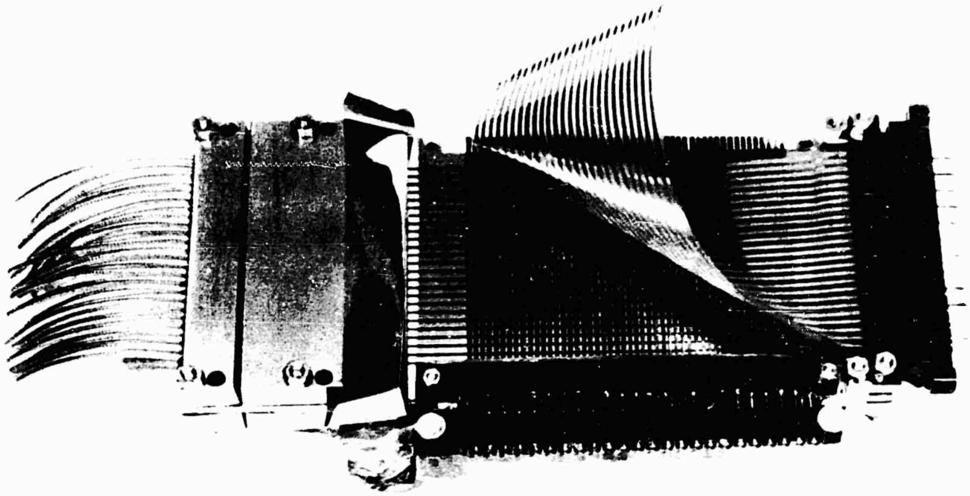

Figure 2. ICT Experimental Thin-Film Memory Assembly

RANDOM-ACCESS MEMORIES

The problem of providing random access to large quantities of stored data has been attacked many ways in the United States and Europe. Two interesting developments in this area are the Carousel memory developed by Facit in Sweden, and the K-10 memory built by Standard Elektrik Lorenz in Germany.

The Carousel (figure 3) permits access to any of over five million stored decimal digits in an average of less than two seconds. It contains 64 small reels of 8-channel magnetic tape mounted in two concentric circles on a wheel. A given reel of tape is read by indexing the wheel so that the selected tape is at the bottom. A weight attached to the end of the tape drops down past an air-gap read/write head to an unwinding bin. Photo-electric sensors control start, stop, and rewind. A fully loaded Carousel wheel can be replaced in about ten seconds.

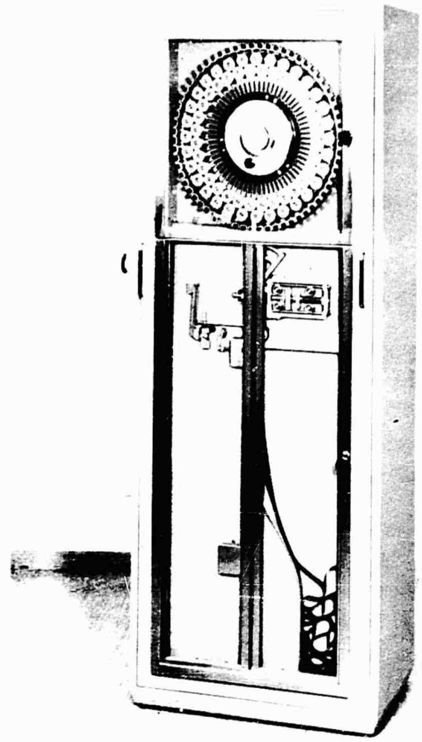

Figure 3. Facit ECM 64
Carousel Memory

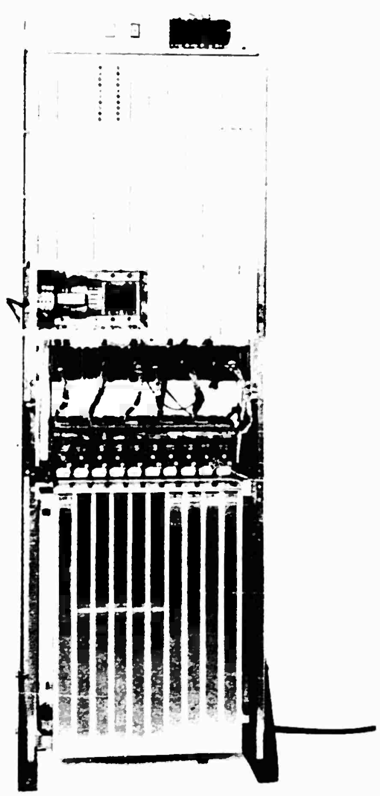

Figure 4. Standard Elektrik
Lorenz K-10 Memory

Standard Elektrik Lorenz' K-10 (figure 4) takes a somewhat different approach to the random-access storage problem. It provides a storage capacity equal to that of a standard tape transport with a 1000-meter tape, but with an access time of only 2.5 percent that of a conventional unit. The K-10 has ten bins, each containing 100 meters of tape. Associated with each bin is a read/write head and a drive mechanism. The tapes normally rest with the mid-point over the head, detected photoelectrically. A typical application uses a crossbar switch, four tape control units, and nine K-10 units for simultaneous reading or writing on any four of 90 tapes.

PATTERN RECOGNITION

The most outstanding development work observed in character recognition in Europe is being conducted at the Technische Hochschule in Karlsruhe, Germany. Solartron in England has produced commercial equipment for character reading. BULL in France, EMI in England, and three German manufacturers are also working in equipment development.

The Karlsruhe approach, sponsored by the German Post Office, is a unique combination of analog and digital techniques. The initial input of a character is straightforward; a flying spot is used to scan the pattern at a rate of 3000 characters per second and the output signal wave is converted to bits indicating black or white areas. The result of a scan is 200 bits (20 vertical by 10 horizontal). A two-dimensional 200-bit shift register stores this image of the original pattern as it develops. The system is currently limited to 14 characters; continued development is expected to increase this number.

The first phase of processing centers the character image. First the character image is transferred from the shift register to an array of 200 flip-flops which in turn feed a resistor matrix. The resistors are so interconnected that there are four output currents: left side, right side, top and bottom. The character is scanned and repeatedly reloaded into the flip-flop array from the shift register with each vertical synchronizing pulse. The character effectively moves from left to right across the array until the left and right currents are equal. This is defined as horizontal centering.

The flip-flops are cross-connected so that vertical shifting of the character image is possible. Then the character is positioned so that the top and bottom currents are equal. This is defined as vertical centering. The horizontal and vertical "centering" place each character image in a unique standard position.

The next phase of processing, which has been thoroughly analyzed but only partially implemented in hardware, is the extraction of salient features from the pattern. Since the currents flowing in the resistors represent the "potential field" (figure 5) of the character stored, it is possible to deduce the key shape features of the character from properties of this potential field. For a simple example, a node with a maximum current inflow indicates the end of a line or an isolated point.

An analysis of first and second differentials of current flow at a point indicates the location and curvature of a line. The sign of the

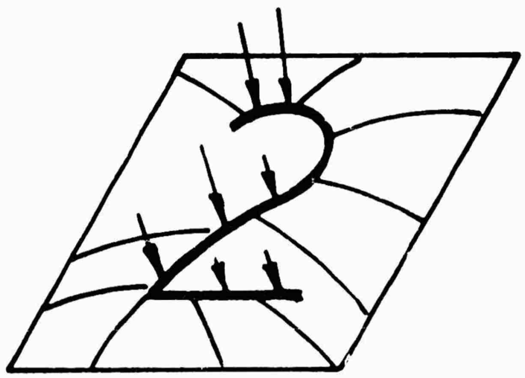

Figure 5. Two-Dimensional Potential Field for the Character "2"

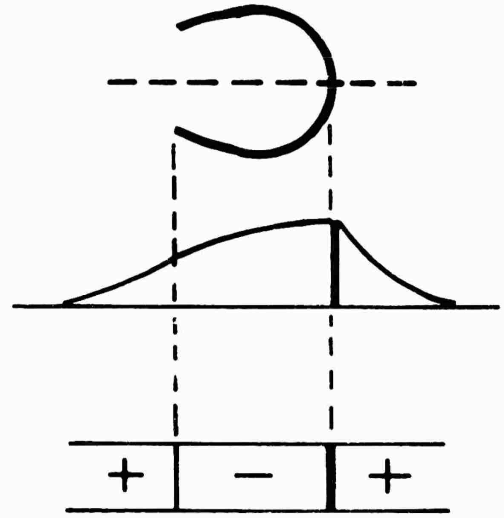

Figure 6. Determining Character Shape by Analysis of Second Differential

first differential indicates whether the character lies to the right or left of the test point. The sign of the second differential indicates whether the line is straight, curved away from or curved towards the test point (see figure 6). Note that these currents and differentials are analog, not digital, phenomena.

To test the first and second differentials, some novel circuits have been devised. The most novel test uses a differential transformer technique. Leads from adjacent nodes of the resistor matrix are wound around ferrite cores with the proper numbers of turns and direction. There are also sense and interrogate windings on the core.

The core is saturated in one direction or the other, depending on the sign of the second differential. An interrogate pulse produces an output only for a positive second differential.

The figures to be recognized are described in terms of the location of major straight lines, the direction of curvature in the upper, middle and lower portion of the figure, and the location of line terminals. The present recognition criteria were selected experimentally and wired into the equipment.

Solartron's commercial character recognition development is the ERA (Electronic Reading Automation), which converts printed character information to punched cards at the rate of up to 240 characters per second. The accuracy claimed is better than one in 10,000 rejects and one in 1,000,000 errors. The complete recognition system includes a scanner, memory, logic, and document handler. The latter provides only for cash register tally rolls, but developments are in process for handling separate documents. A Solartron ERA system was observed undergoing final factory tests in July, 1960.

The ERA is designed to read numerals (0-11), plus some alphabet characters and special signs. Models are under development for sensing additional characters. The sensor uses a flying-spot scanner and a photoelectric pickup, and prescans each character twice. The first prescan establishes peak white and black levels, which clamp the limits to a narrower range than would otherwise be necessary, thus compensating for smudging and other irregularities. The second prescan establishes x-y limits to center the character; then a final scan transfers the character information into ferrite-core storage. Each character has its own

criteria stored within the machine; both acceptance and exclusion criteria are used for identification.

Three of the larger German computer manufacturers (Telefunken, Siemens, and Standard Elektrik Lorenz) have also been working on character recognition equipment, in an effort to receive contracts for equipment to mechanize the German Post-Check system and the German Post Office letter-sorting problem. Telefunken has a pilot model reader for American Banking Association characters under test.

Electric and Musical Industries (EMI) in England is developing a character reader named FRED (Figure Reading Electronic Device).

MACHINE LEARNING

Exploratory work in learning machines, most of it in the early stages, is being pursued by several European groups, notably the Technische Hochschulen in Vienna, Austria and Karlsruhe, Germany, and Manchester University and Solartron in England. Unfortunately, little information is available on these activities, other than an indication of the general approach each group is taking.

In Vienna, programs are being developed for the MAILUEFTERL computer to create a new type of conditioned-reflex automaton. An improved model of Shannon's maze runner has also been developed, with the ability to detect circle-ways, resolving them into parts of the solution.

The Karlsruhe group has devoted much study to the philosophy of learning machines, and has produced some excellent articles summarizing the accomplishments in the field. Their work, like that in Vienna, is concerned primarily with conditioned reflexes and is closely related to their developments in character recognition. One approach to the conditioned reflex problem uses the multi-step characteristic of ferrite cores in a matrix, with the sensors connected to one axis and the reactors to the other. By repeatedly exposing the sensors to the situation, a conditioned reflex is built up so that when the reactors are interrogated a learning-type reaction is obtained. In addition to character recognition, applications of this technique are seen in information retrieval and automatic speech recognition.

At Manchester University, one problem under investigation involves control of a configuration of water tanks in which some drain into others, some drain into a sink, and some are filled from an external source. All flows are controlled by valves, some of which operate randomly while others are controlled by a learning machine. The machine is told only which tanks are too full or too empty, and must try to maintain the proper levels without knowing how the tanks are interconnected or what the valves control. Such a machine may find application in chemical processing.

Another learning problem under study at Manchester involves the memory organization of the MUSE (ATLAS) computer. To achieve, in effect, a huge fast-access memory, MUSE combines a magnetic core memory and a drum

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memory such that information is transferred between the memories without direction from the programmer. The computer's task is to keep those data which are frequently requested in the immediate-access core memory, with less-used data on the drum. When a given block of information is requested, it is read out immediately if in core storage, or transferred from the drum in exchange for an unused block in the core memory. Learning criteria are being developed so the computer can maintain the best compromise of storage locations at all times.

Solartron's association with Rheem Manufacturing Company in the United States has resulted in the development of Eucrates, an experimental teaching and learning machine. Learning is accomplished by storing the number of hits in correlating a keyboard and a selected light. As the number of hits is increased, the "pupil" part of Eucrates "learns" the correlation, and eventually selects the right key. To simulate human behavior, a "forgettery" control is introduced that requires continuous enchancement. The "pupil" learns under control of the "teacher" part of the equipment, or on a trail-and-error basis without outside assistance.

Solartron has also developed a teaching machine, the SAKI (Solartron Automatic Keyboard Instructor), which trains operators in the use of punch-card equipment. The SAKI consists of a keyboard, a power supply, and a control unit. On the latter are two indicators, one corresponding to the location of the keys and the other a card with rows of random numbers and/or letters. In operation, a light shines behind each

of the characters on the card, in sequence. The corresponding keyboard indicator is also illuminated, telling the trainee which key to depress. As the proper buttons are depressed, the keyboard indicators grow dimmer and the presentation rate is increased. If errors are made, the rate is reduced and the indicators gradually come back on again.

HYDRAULIC LOGIC

One of the most interesting and unusual developments in Europe is the work being done at IBM's Zurich Laboratory on hydraulic logic. This is exploratory work aimed at establishing basic techniques rather than building hardware.

This application of hyraulic techniques is quite different from the conventional usage where high power is used to move heavy external loads. In hyraulic logic there is no external load, thus permitting lower pressures and much smaller elements. Miniaturization also permits higher speed, and hydraulic elements compete favorably with relays in this area of performance. Laboratory models of a free-running multivibrator have been operated at 300 cps, and calculations indicate that, with care, 2000-cps operation can be achieved.

Although hydraulic elements can take many forms, the devices built by IBM Zurich use "spool" valves, shown in both schematic and symbolic form in figure 7. In this simple building block, three inputs (A, M, and N) and one output (X) are provided. Logical signals in the form of high and low pressure (corresponding to the voltage/no-voltage

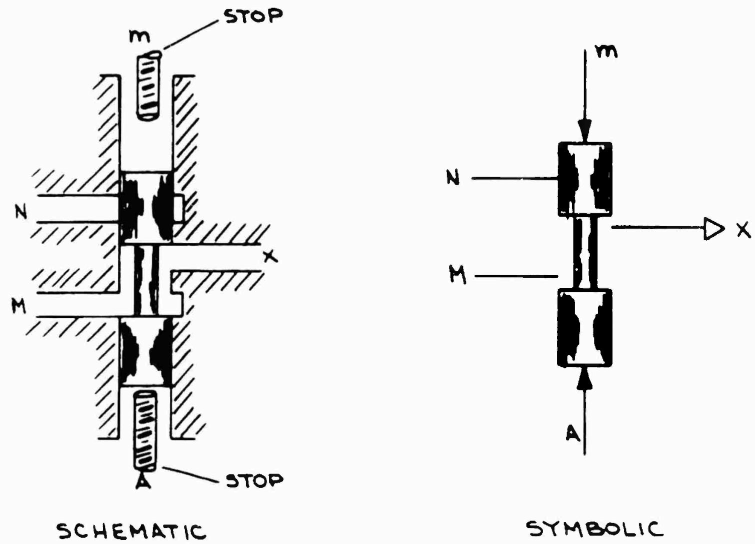

Figure 7. Basic Hydraulic Logic Element

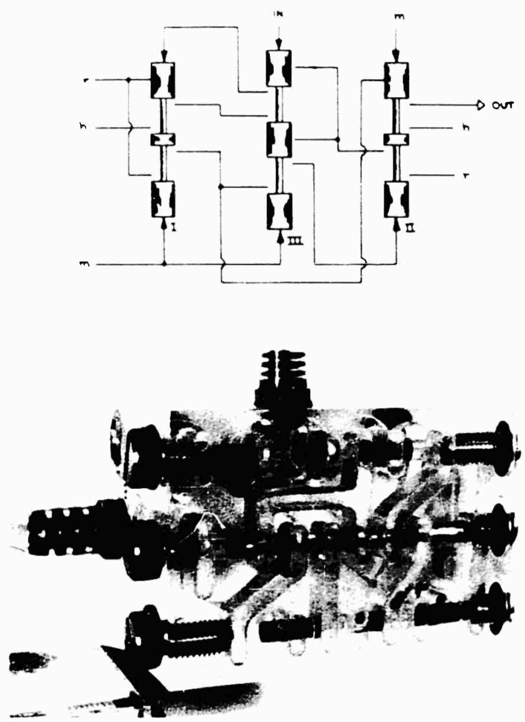

Figure 8. Hydraulic Scale-of-Two Counter

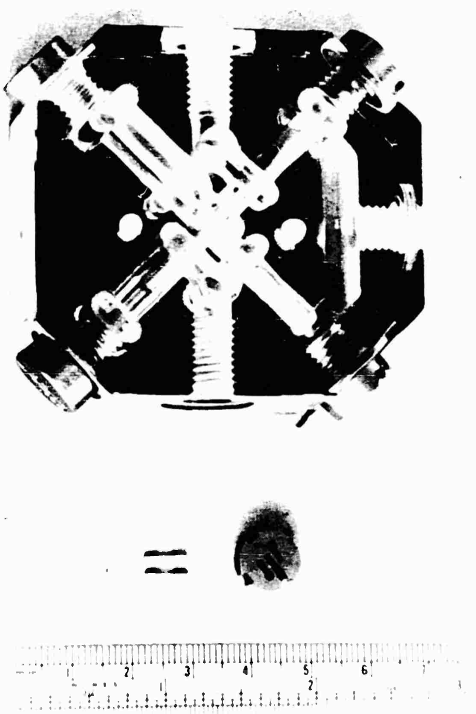

Figure 9. Hyraulic Multivibrators, 1mm and 5mm bores

levels in electronic binary logic) are applied to the inputs. A static medium pressure is applied to m. Thus the pressure at A determines the position of the valve, which in turn defines, together with the input at M or N, the pressure at X. If high pressure is regarded at logical ONE and low pressure as logical ZERO, the performance is described as

$$X = MA' + NA$$

The logical capability of the hydraulic element is thus greater than that of a single transistor.

By providing a feedback path from X to A, a bistable element is created. These simple configurations - the gate and the bistable device - are the basis for all other hydraulic logic elements. Gating networks, shift registers, counters, matrices, and multivibrators have been built and successfully operated. Figure 8 shows the logical diagram of a scale-of-two counter and working model of this unit. Figure 9 shows two multivibrators, with bores of five and one millimeter, respectively. The larger models are fabricated in clear plastic, to permit direct visual observation of operation using stroboscopes and high-speed photography.

Hydraulic logic presents many serious design problems. In many respects the elements behave like their electronic counterparts, resulting in such problems as transient peaks when current in an inductive circuit is suddenly stopped. In addition, many physical effects relating to fluid flow influence the design. Inertia is especially critical in determining response time, and channel (i.e., conductor) lengths must be equal for two parallel-fed elements to operate synchronously.

Despite these problems, the IBM Zurich group has made an impressive start toward realization of practical control and decisioning equipment using hydraulic elements exclusively. They admit that a hydraulic computer is in the far distant future, but point to more immediate potential applications, such as process control and machine tool control. They feel that the high reliability and long life of hydraulic components make the technique especially attractive in such applications.

ALGORITHMIC PROGRAMMING LANGUAGE (ALGOL)

In late 1955 Professors Samelson and Bauer of the Technische Hochschule in Munich, Germany, originated an idea for an easily understood computer input language and an efficient system of converting this language into machine codes. They began developing conversion principles in 1956, and in early 1957 made contact with Professor Rutishauser of the Technische Hochschule in Zurich, Switzerland. In 1951 Professor Rutishauser had stated the problem of algorithmic languages and given a possible solution, which was generally overlooked at that time.

The three men set up a cooperative group which included Dr. Bottenbruch of Darmstadt, Germany, and submitted a preliminary language proposal to a German technical society (GAMM) programming committee which approved it in 1957. The Association of Computing Machinery in the United States was contacted in 1958 to establish a unified language. An ALGOL Conference was held in Zurich in June 1958, followed by the second ALGOL Conference in Paris in 1960. Meanwhile, Professors Bauer and Samelson moved to the Johannes Gutenberg Universitaet in Mainz, which became the new center of activity.

One of the original goals in the translation of algorithmic languages to machine language was to achieve conversion in a single-pass read-in program. No large-scale sorting or searching for patterns by back-and-forth scanning of the source information was possible, since the computers available in Europe at that time did not have large internal memories or fast peripheral storage. A technique adopted to meet these requirements is the "cellar principle", wherein information which cannot be evaluated upon reading is stored temporarily in one or more "cellars" (sometimes called "stacks" or "push-down storage").

Most computer groups on the Continent, including a few in the USSR, are working on or have completed ALGOL-60 translators for their machines. ALGOL has been integrated into courses on numerical analysis, and students with very little training can write programs for their numerical problems. Experience has shown that program debugging and improvement is easy. Work continues at Mainz on improving the efficiency of programs and the expansion of the language to handle index registers, heterogeneous internal memories and magnetic tape units. Based on the development of ALGOL, interest is shifting to other forms of language conversion.

NON-DESTRUCTIVE ACOUSTIC DELAY LINE

Elliott Brothers have observed an interesting phenomenon that can be used for non-destructive storage with nickel delay lines. A bit of information is stored in a nickel wire by discharging a capacitor through

the wire at a fixed point. Bits may be placed at intervals of one-half to one centimeter along the wire, equivalent to approximately one microsecond intervals. The discharge applies a permanently stored circular magnetization to the wire. Passing a current pulse through the wire sets up an acoustic wave from each bit stored so that an acoustic coil transducer, mounted on the wire past the current output, will receive a sequence of acoustic signals corresponding to the stored discharges in the wire.

III-REVIEW OF EUROPEAN ACTIVITIES

The following is a digest of material gleaned by the author through personal visits and from volumes of technical data from companies and organizations in Europe actively engaged in the information processing industry. The order of presentation approximates the author's itinerary. The material conveys the author's impressions as well as extra technical details whenever the visit being reported permitted close observation of an equipment or technique. In other cases, only general information is presented on a group's activities since detailed information was not made available.

GREAT BRITAIN

Computer activity in Great Britain is second only to that in the United States. Some of the early pioneering work in electronic computation was done in England; e.g., the first internally programmed electronic computer, EDSAC I, was completed at the Mathematical Laboratory of the University of Cambridge under the direction of Professor Maurice Wilkes. Universities continue to play an important role in advanced computer development in Great Britain.

The application of computers in business is gaining acceptance in Great Britain, and most of the production of the British computer industry is for domestic use. Table I lists the computers that were installed or on order in Great Britain as of July, 1960.

LEO COMPUTERS LIMITED

Leo Computers Limited is a wholly owned subsidiary of the J. Lyons & Co. Limited of London, which controls a chain of teashops and hotels and several large food manufacturing plants. Lyons has for many years been a leader in management accounting, and was one of the first to set up a clerical research department in Great Britain. A visit to the ENIAC installation in the United States in 1946 convinced Lyons management that computers could be utilized for office use. Finding no one capable of building a computer for them, they decided to build their own.

TABLE I - ELECTRONIC COMPUTERS IN GREAT BRITAIN

NAME OF COMPUTER	NO. INSTALLED	NO. ON ORDER	TOTAL
AEI 1010	1		1
EMI 1100	5	9	14
EMI 2400		2	2
English Electric: DEUCE	25	3	28
English Electric: KDP 10		2	2
Ferranti: MK I & MK II	9		9
PEGASUS	25	13	38
MERCURY	15	4	19
PERSEUS	2		2
SIRIUS	1		1
ORION		8	8
ATLAS		1	1
IBM RAMAC 305	2	2	4
650	13		13
704	2		2
705		1	1
709	1		1
1401		40	40
ICT 1200	7		7
1201	41	2	43
1202	8	17	25
1301		17	17
LEO I	1		1
II & IIC	10	1	11
III		2	2
Elliott: NICHOLAS	4		4
ECCLES, 401, 403			
402, 402E, 402F	10		10
405	27		27
609	2		2
802	7		7
803	12	12	24
STANTEC ZEBRA	32	10	42
TOTALS	255	151	406

The project was started in 1947 and by 1951 LEO I was completed, based on EDSAC I. Trials, development and expansion continued to the end of 1953 when satisfactory input and output equipment had been devised. Since 1951 LEO I has been solving mathematical problems and since 1954 it has been used to automate office procedures and to provide service bureau clerical functions to other English companies. LEO I is the oldest computer in the world still in operation and it shows every sign of continuing to be mechanically and technically sound.

On the basis of experience with LEO I a decision was made in 1954 to design and build LEO II computers for both direct sales and for use in service organizations. The first of these machines began service bureau work in 1957 and since then seven have been completed. There are three LEO service bureaus in operation in London.

LEO Computers Ltd. offers a complete computer service: design, construction, installation, training, servicing, and programming, backed by service bureau support. Of interest is the fact that the company assumes the responsibility for the first suite of programs run on each computer that is sold or rented. LEO has attained an excellent reputation in England for its knowledge in applying computers productively in business and for its contributions to the field.

In the summer of 1960 LEO Computers announced LEO III, a completely transistorized parallel computer (see detailed characteristics in table I). LEO III has three distinctive features. The first is that the basic

actions are controlled by micro-programs; a machine instruction is carried out by a step-by-step series of elementary operations or any simultaneous group of operations contained in the wired magnetic-core planes. The second feature is the ability to micro-code the computer to operate as a multi-radix computer. The radices can be varied easily between binary, decimal, and sterling, for example. The third feature provides for the simultaneous operation of two or more different programs under control of a master program.

UNIVERSITY OF MANCHESTER

The University of Manchester's computer engineering laboratory originally directed by Professor Fredrick C. Williams (now head of the Electrical Engineering Department at Manchester) and now directed by Professor Thomas Kilburn (recently appointed to the newly established first chair of computer engineering in England) has been responsible for many developments in the computer field. .This group developed the Mark I and Mercury computers manufactured by Ferranti, and is now developing the MUSE computer to be manufactured by Ferranti under the name ATLAS.

The Mark I was completed in 1951 and did a prodigious amount of work until it was retired to a museum in 1958. The Mercury built by Ferranti has been operating 24 hours per day at the University since 1957. The MUSE is being developed and designed at the University of Manchester by a combined team of University and Ferranti engineers under Dr. Kilburn's direction. The first ATLAS will be assembled during 1961.

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The MUSE is based on advanced development work in high-speed solid-state circuits and an extremely sophisticated organization. It is intended to work with a wide variety of up to 256 peripheral equipments to satisfy both scientific computation or commercial data processing requirements.

One of the outstanding features of MUSE (see Section IV for details) is a novel adder-carry circuit that gives a fixed-point addition of two 48-bit words in 0.25 microseconds, and floating-point addition in 1.1 microseconds.

The organization of the magnetic core and drum memory gives an effectively hugh internal storage capacity. Up to one million words can be addressed in the main store; a typical system might have 16,000 words of core storage (cycle time of 1.3 microseconds) and 100,000 words of drum storage (5000 rpm). Information is exchanged between the two memories automatically, without direction from the programmer. An internally stored program for transferring the least referenced "pages" (i.e., 512-word block) to drum storage is supplied. Other learning criteria are being developed to establish which page should be exchanged in the transfer.

Each page of information retains its unique identity regardless of where it is stored. A flip-flop register associated with the core memory identifies each "page" of information currently held in that location. When information is requested its page identification is rapidly compared with the contents of the flip-flops. If the desired information is located

in the core store, it is read out immediately; if not, it is located in the drum memory and transferred to core store (in exchange for an unwanted block), then read out. Other operations may be interleaved during this transfer.

In addition to the main store a "fixed store" is provided for storing constants, sub-routines, and program organizing routines. This fixed store, a new device developed by the Manchester group, consists of ferrite rods inserted into a wire mesh (see details in part II). It has a capacity of 8192 words, an access time of 0.2 microseconds, and a 0.4 microsecond cycle time. (A similar smaller memory system is being built at the University of Pisa from the wire mesh supplied by Kilburn.)

An internal subsidiary core memory of 1024 words is provided, alterable only by the program in "fixed store". The programmer does not have direct access to this memory, which is used for such things as variables and for storing the locations of the next word. An additional 100-150 words of "V-Store" are provided to control peripheral equipment.

Up to 32 magnetic tape units (Ampex FR-300A) can be attached to the computer via tape control units. Up to eight may operate simultaneously, either reading, writing, or searching at 90,000 characters per second. Other available input/output includes four paper tape readers, four paper tape punches, one xerographic printer and a graphic display unit. All of these peripheral equipments can operate simultaneously.

Over 300 instructions are available for programming MUSE. Included are basic operations and "extracode" operations. The latter, indistinguishable to the programmer from the basic instructions, initiate special subroutines for more complex operations.

Automatic programming techniques are being developed for ATLAS. Covering both mathematical and data-processing applications, the automatic programming will accept programs written in the AUTOCODE system devised for the Ferranti MERCURY computer, as well as FORTRAN and ALGOL codes.

In addition to the MUSE project, research on magnetic thin film and electroluminescent techniques continues under the direction of Dr. G. R. Hoffman. A 16-inch-square 512x512 coincident-voltage electroluminescent display has been demonstrated. Dr. R. L. Grimsdale is supervising work in machine learning and pattern recognition. The learning work is directed toward getting a computer to write its own programs based on experience, as, for example, in the MUSE core-drum transfer.

FERRANTI LTD.

Ferranti Ltd. was one of the earliest companies in Great Britain to enter the computer field, beginning with the Mark I development with the University of Manchester in 1951. Since then Ferranti has produced a large family of electronic digital computers, and the company is today at the forefront of technological developments and scientific computation in England. The characteristics of each of the many Ferranti computers are summarized in Section IV. Some of the more recent developments are noted below.

The SIRIUS is a small decimal computer with nickel delay line memory and punched tape and card input-output. It was produced in 1959 to prove the "Neuron" building block concept, a standardized linear ferrite core-transistor element from which the entire logic and the vast majority of the computer is built.

ARGUS is a process control computer developed in 1960 with a 12-bit word and 57 instructions. It is peg-board programmed.

The ORION, a large-scale commercial data processor with a vast array of input-output equipment, will be marketed in 1961. It is a sophisticated multiple-program computer assembled from the "Neuron" elements used in SIRIUS. The fabrication techniques used for ORION were the most advanced observed in Europe. Printed-circuit cards plug into chassis which are assembled on a twin-door cabinet. The cards are interconnected with wire-wrapped backplane wiring, and the chassis connected to other chassis on the same or different doors through molded flexible multi-conductor flat strips.

The ATLAS computer, jointly developed with the University of Manchester and described in the previous section, will be available in 1962. It is the most advanced computer, from the system organization, circuit techniques and memory design points of view, being developed in Europe at the present time.

Ferranti also manufactures a business transactor, high-speed paper tape readers, magnetic drums, nickel delay lines and other computer

equipment that may be found used on non-Ferranti systems. They maintain a large service bureau in both London and in Manchester.

The computer industry in England regards the automatic programming work being done by Ferranti as the best in the country.

ELLIOTT BROTHERS

Elliott Brothers is a division of Elliott Automation, a holding company founded in 1801. Elliott is an aggressive, dynamic firm, directing its attention primarily to the field of scientific and industrial application and automation fields of electronics.

Elliott entered the general-purpose computer field in the early 1950's, producing several serial scientific machines. These computers (NICHOLAS, 401, 402, 403) were characterized by nickel delay line storage and vacuum tube/diode logic.

The first business data processing machine made by Elliott was the 405 computer, which was based on the same tube/diode logic as the earlier system and included a magnetic (35mm sprocketed) film memory and a 16,000-word magnetic disc memory with simultaneous transfers to the working store of nickel delay lines from these units and the central processor.

A marketing agreement was concluded in 1956 with the National Cash Register Company for the sale of Elliott computers for business applications in Great Britain, Europe and many parts of the world outside the United States.

In 1958 Elliott introduced the partly transistorized 802 computer which was followed almost immediately by the completely transistorized 803. The latter, which incorporates a 4,096-word ferrite core working memory, is being marketed in three areas; as a small-scale scientific computer (the basic machine with paper tape input and output); as a small-scale business data processor (with magnetic film storage); and as the computer unit of the ISI 609 on-line industrial data processing system. Extensive laboratory simulation studies were underway in June 1960 on the use of various kinds of computers and the criteria involved for real-time computer process control. The 803 is enjoying wide interest throughout the world as shown by sales in the United States (in the form of the 609), England and the Continent, and in the U.S.S.R.

Input/output for the 803 consists of punched tapes and cards; however, any device capable of transmitting digital data can be attached (e.g., a digital clock or, via an analog-to-digital converter, thermocouples, pressure gauges, flow meters, etc.). Bulk storage is obtained by attaching the Elliott 35mm magnetic film unit. Each film reel holds 262,144 words and information can be transferred to core storage in 64-word blocks.

Elliott has announced a new computer, the 503, which is to be a large high-speed scientific machine similar to the 803. The high-speed circuitry in the 503, similar to that developed by the University of Illinois, uses transistors with an alpha cutoff of 60 megacycles and operates

in the non-saturating mode. The signal levels are zero and one volts and the pulses used in this circuitry are 45 millimicrosecond duration with an 8-10 millimicrosecond rise time. The flip-flop uses seven transistors and five diodes. The measured delay per stage in this type circuitry is 30 millimicroseconds. The memory is a magnetic core type of 1,024 words, 20 bits per word. Cycle time is one microsecond. Input/output can be two monitor typewriters, multiple units of the Elliott paper tape readers (1000 characters per second), Teletype punches (100 characters per second), Elliott Card Readers (400 cards per minute), the IBM Card Punch (100 cards per minute), Potter tape transports (279,000 bits per second) and a line printer (900 lines per minute).

Elliott is doing advanced development in the fields of wired cores memories, transistor/resistor NOR circuitry, and nickel delay line storage (see part II).

Elliott is well diversified in the fields of analog computers and peripheral equipment. The unit construction principle is used in the manufacture of their equipment and most orders are custom specified.

Elliott operates a major computing center at its Borehamwood, Hertfordshire plant. Used primarily to develop new programs and explore new applications for computers, the center includes two 405 computers, two 402 computers, an 802 and an 803. Peripheral equipment includes a BULL off-line printer and magnetic tape-to-paper tape (and vice versa) converters.

In addition, NCR maintains three computing centers in England operating 405 computers on a time rental basis.

EMI ELECTRONICS LIMITED

EMI Electronics Ltd., a wholly owned subsidiary of the 35-year-old Electric & Musical Industries Ltd., was formed seven years ago and manufactures professional electronic equipments including military electronics, industrial television, nuclear instruments, machine tool control systems, and analog and digital computers. EMI Electronics employs about one-third of the total 34,000 EMI personnel. From 1930 until his untimely death in World War II Mr. A. D. Blumlein was Chief Engineer of EMI and was a pioneer who has been credited with developing television, TV broadcasting systems, and many of the electronic circuits in radar. EMI was the leader in electronics in England.

EMI, known for its work in analog control systems, decided to enter the general-purpose electronic digital computer field a few years ago. Its first commercial machine, the EMIDEC 1100, used transistors and magnetic cores in dynamic circuitry mounted on printed-circuit cards. The 1100 is a two-address binary parallel machine with a 36-bit word. Memory consists of a 1,024-word magnetic core storage and a multiple number of drums in either 8,192-or 16,384-word size. Up to 16 peripheral units may be included in the system. Input/output is magnetic tape (modified Ampex FR-300), card or punched tape, and printer. Each peripheral unit is connected to the computer through double buffers,

thereby minimizing the need for a fast interrupt. Operation times are approximately 125 microseconds for addition and subtraction, and 1.1 milliseconds for multiplication and division. Microprogramming is achieved by a wired 80 x 20 matrix of magnetic cores. There are 128 wires in the matrix, and almost all instructions require some microprogramming to execute. In July 1960 there were 14 EMIDEC 1100's ordered, of which five had been delivered.

In 1955 the National Research Development Corporation contracted with the EMI Electronics to design and develop an advanced data processing system. This system, the EMIDEC 2400, is a very large high-speed data processor comparable to the IBM 7080. It has a highly sophisticated organization of on-line and off-line peripheral equipment. In July 1960 the original computer had been operating for 18 months and the whole system for 12 months. Two 2400 systems had been sold and were under construction. EMI plans to manufacture four systems per year.

The 2400 uses 1-megacycle transistor-diode logic operating in the parallel binary mode. Magnetic core storage is used for working data, supplemented by a small diode-capacitor store for control functions. Input data from such devices as keyboards, paper tape punched cards, etc. are converted off-line to 1-inch magnetic tapes which are then used as input to the central processor. Similarly, the computer output is recorded on magnetic tape, which feeds off-line such output devices as card punches,

tape punches, and printers. A Rank xerographic printer is available for high-speed output (3000 lines per minute). In addition to the off-line facility, the central computer also has a slow-speed on-line input/output facility, for direct communication with paper tape or card units, printers, etc.

For bulk storage of data, 4-inch magnetic tape file search units are included in the off-line equipment. One 4-inch tape provides storage for over 25 million characters. The file search is controlled by a 1-inch tape unit prepared by the computer, and the information extracted from the bulk storage is prepared on a 1-inch tape for input to the computer. Both tape units operate at the same data rate, 20,000 characters per second per channel. The 1-inch unit has two parallel channels of 12 tracks each, while the 4-inch unit has ten channels of nine tracks each. The file search unit also includes a 512 x 14-bit core memory for temporary storage.

Special features of the 2400 include automatic inter-unit switching of peripheral units, with an interrupt facility to permit breaking into the normal computing routine for peripheral unit control; elaborate error checking; and time-sharing of computing and input/output functions.

The 2400 is constructed from printed circuit plug-in modules of 50 basic types, and contains 20,000 transistors and 60,000 diodes. The core memory is built from 4096-word stacks into 16,384-word modules.

Eight prototype magnetic tape transports designated the EMI Tape Deck 410 had been operating for over 12 months in July 1960. These tape units use a vacuum capstan with electrostatically controlled bin reservoirs. The 1-inch tape provides for 24 tracks, only 12 active at one time, each track interspaced to minimize the effect of contiguous faults. Data occupies six tracks, and error-correcting code four tracks and a dual clock two tracks. The data is recorded at 100 frames per inch and the tape moves at 200 inches per second. The engineering of the EMIDEC 2400 and the tape deck stressed reliability to a higher degree than most other equipments seen.

There is a sizeable programming staff developing routines, compilers and assemblers for the 2400.

The company produces a character reading device called "FRED" (Figure Reading Electronic Device), which converts printed figures into magnetic tape code. Details of this development were not available.

In machine tool control, EMI has applied its analog control equipment to a Cincinnati Hydrotel miller for cutting contours; and has an agreement with Cincinnati Milling Machine Company for marketing the control system of millers. EMI also has an agreement with Fairbanks-Morse for the general exploitation of the machine tool control market other than millers in the United States.

INTERNATIONAL COMPUTERS AND TABULATORS LIMITED (ICT)

ICT was formed in January, 1959 from the British Tabulating Machine Company, Limited (Hollerith) and Powers-Samas Accounting Machines Ltd. The company is one of Great Britain's largest manufacturers and distributors of business machines, with 23 factories and 17 service bureaus. It produces and services a complete range of data processing equipment from punched-card equipment to large-scale advanced computers. A thin film research project is being conducted at the laboratories in Stevenage, Hertfordshire (see part II for details).

The 1202 is a small, general-purpose, stored program, 2-address machine built in 1959. It followed the 1201, a 1,024-word drum version built in 1956. The 1202 has a 600-cards-per-minute photoelectric card reader, a 600 lines-per-minute printer and a 100 cards-per-minute punch. Drum storage is provided, with a capacity of 4,096 50-bit words.

In November 1959 International Computers and Tabulators Limited and the General Electric Company Ltd. formed Computer Developments Ltd. as a jointly owned design and coordinating group. The 1301 computer, the first outgrowth of this united effort, is a file processor for medium-size companies. ICT will manufacture the peripheral equipment and market it through its world-wide channels. General Electric will manufacture the electronics. At present there are two production prototypes of the 1301 in construction, with a backlog of 17 orders.

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The 1301 is a fully transistorized 1-mc binary-coded decimal serial-parallel machine. It has a magnetic core memory with a capacity of from 400 to 2,000 words and up to 96,000 words of drum storage. It operates with a 12-digit word, a single-address system and can add in 21 microseconds. It has simultaneous input-output with a 600 cards-per-minute card reader, a 600 lines-per-minute drum printer, and a 100 cards-per-minute card punch.

Two types of magnetic tape systems are available with the 1301, for external storage or input/output. Up to eight tape units of either type may be used with the system. The "high-speed" system uses 1-inch tape divided into 16 tracks, and operates at 150 inches per second, 600 digits per inch. Start/stop time is 7.6 milliseconds. The "Standard" system uses 1/2-inch tape divided into ten tracks, operating at 75 inches per second, 300 digits per inch. Both tape systems feature automatic error detection and correction.

A full library of service, mathematical and commercial routines has been completed. ICT has established an auto-code library whereby customers exchange programs with the main library. The 1301 will also offer an automatic coding system based on COBOL.

STANDARD TELEPHONES AND CABLES LTD. (STC)

STC, an ITT affiliate, was founded in 1883, and for many years has been active in telephone and radio communication, power control equipment, and automatic reservations systems. The Company's entry into electronic data processing came in 1958, when the first STANTEC ZEBRA was produced.

This simplified binary serial general-purpose computer was designed under the direction of Dr. ir. Willem van der Poel, of The Netherlands Postal and Communications Services. STC manufacturers and markets the ZEBRA, and by July 1960 had installed 32 computers with 10 orders yet to be completed.

The main storage consists of a magnetic drum with a capacity of 8,192 33-bit words. The drum rotates at 6000 rpm and has 256 parallel tracks, with an average access time of 5 milliseconds and 12 fast-access drum track registers for storing partial results.

The input to STANTEC ZEBRA is punched paper tape with a speed of 200 characters per second. Two output devices are provided; punched paper tape at a speed of 25 or 50 characters per second, and on-line printing at a speed of 420 characters per minute. Printing and punching devices designed to work at much higher speeds are under development. (See section IV for details.)

Among the unique features of the computer is the use of large etched circuit boards for interconnections between the vacuum-tube plug-in modules, extensive use of microprogramming, and the use of all "short" storage registers as instruction modifiers. In addition to the normal machine code, a "simple code" has been designed especially for the unskilled user. A large library of proven sub-routines is available.

STC is currently producing the STANTEC COMPUTING SYSTEM, the heart of which is a transistorized and improved version of the STANTEC ZEBRA.

The system is tailored to any of a wide variety of requirements by combining the basic computer with a broad selection of peripheral equipment.

In the STANTEC COMPUTING SYSTEM the magnetic drum is supplemented with ferrite core fast-access storage. Up to 16 blocks of ferrite core storage in multiples of 512 words can be connected in parallel with the drum. Either drum or core memory can be selected by the program. Buffer storage is available in ferrite blocks of 32 words; up to eight such blocks may be linked to the system.

Normally three types of tape units can be used. The K2 Magnetic Tape Unit, using an open strip of tape 100 meters long contained in two magazines, can contain up to one million alpha-numeric characters. The K10 Magnetic Tape Unit, consisting of ten K2 tapes integrated in one frame and having a common drive motor, can store up to ten million alpha-numeric characters. (See Standard Electric Lorenz, Germany, for details.) The K2S Reel Tape unit is equipped with tape reels (2400 ft or 3600 ft) which can store up to 12 million characters. Tape control is initiated by the novel system of balancing the weight of tape in one magazine against the weight of tape in the other.

A STANTEC COMPUTING SYSTEM can have a maximum of six paper tape readers (300-800 characters per second); two teleprinters; six paper tape punches (50 characters per second); one card reader (340 cards per minute); one card punch (150 cards per minute); one "block" - type paper tape reader,

one "block" - type paper tape punch, 64 K2 or K2S magnetic tape units, and one xeronic printer (3000 lines per minute).

CAMBRIDGE UNIVERSITY

The Mathematical Laboratory of Cambridge University, under the direction of Dr. Maurice Wilkes, was responsible for the construction of the first internally stored program computer, EDSAC-I, in 1949, following the tenets established by Dr. John von Neumann. Another innovation was registered with the design and construction of EDSAC-II, which used wired-core microprogramming. The 1000-character-per-second photoelectric paper tape reader manufactured by Elliott was patterned after the model built at Cambridge.

ENGLISH ELECTRIC COMPANY LTD.

In 1947 the National Physical Laboratory at Teddington, England formed an Electronics Section under the direction of Dr. Booth to undertake the design and construction of an electronic digital computer, designated ACE. Because of the size and complexity of the planned machine it was decided to build a smaller pilot model to prove techniques and gain programming experience. The pilot model was a serial machine with a 1-KC pulse repetition rate. It used 800 vacuum tubes and mercury delay line storage, with punched-card input and typewriter, punched-card, and gang printer output. The pilot model was so successful that it was put into regular service; later, a magnetic drum was added to increase the memory capacity.

In 1952 the English Electric Company of Manchester was given the task of designing an engineered model of the ACE design, with expanded capability. The result was DEUCE (Digital Electronic Universal Computing Engine). Like ACE, DEUCE is a vacuum-tube serial machine. The mercury delay storage consists of 12 long lines, each accommodating 32 words of 32 bits each; four short lines, one word each; three short lines, two words each, and two short lines of four words each. The 6,500-rpm magnetic drum back-up storage has a capacity of 8,192 words.

Later revisions of DEUCE featured expanded memory capacity and a wider selection of peripheral equipment, to meet the demands of commercial data processing. Magnetic tape units and paper tape equipment were added to the punched-card input-output system.

An advanced and well designed machine for its day, DEUCE was favorably received. As of July, 1960, 25 systems had been sold and three were on order.

The English Electric Company has an agreement with RCA to produce a transistorized medium-size data processing system patterned after the RCA 501. The English version is designated the KDP10 and is physically and functionally similar to the RCA system.

SOLARTRON ELECTRONIC GROUP LIMITED

Solartron is a young and aggressive company working exclusively in electronics. The company has expanded rapidly since its inception in 1948 and currently employs over 1,000 people in 12 separate operations.

Solartron's activities include electronic instruments, radar simulators, analog computers and trainers, countermeasures, and antenna simulators. Some advance development work is being done in the area of character recognition and teaching and learning machines, under the direction of C. E. G. Bailey.

The ERA (Electronic Reading Automation) device reads alphanumeric characters and produces information for direct use by computers or punched-card machines. Conversion rates of up to 240 characters per second have been achieved, with an accuracy of better than 1 in 10,000 rejects and 1 in 1,000,000 errors. The first production ERA was in final test and two more systems are on order. (See details in part II.)

Solartron has an agreement with Rheem Manufacturing Company whereby the two companies exchange patents. Both companies are working on teaching and learning machines, with Solartron specializing in pyscho-motive teaching machines. The Solartron Automatic Keyboard Instructor (SAKI), being marketed in the United States by Rheem, trains operators in the use of card punch equipment. It greatly reduces learning time and makes it possible to "weed out" persons who do not have the required learning ability in less than two hours. (See details in part II.)

An experimental learning machine, Eucrates, was built by Solartron for Rheem. The device includes three units: a "Teacher", a "Pupil", and a control unit. The "pupil" learns to correlate a bank of indicator lights with a keyboard, under direction of the "teacher", or by trial and

error without guidance. Eucrates is regarded by Solartron as an experimental tool which may lead to a further understanding of a mechanical pupil.

Solartron's analog computer line consists of basic computing elements, two computers, and an "Analog Tutor" for teaching or demonstrating analog techniques. The MINISPACE computer is a small-capacity, high-accuracy, general-purpose unit incorporating ten operational amplifiers.

The SPACE 30 is a larger general-purpose analog computer composed of the same basic modular elements used in the smaller equipments. It has 30 operational amplifiers (hence the nomenclature) and features high accuracy and simplified operation. Solartron is producing the SPACE 30 both for sale and for use in its Computer Center, and as of June 1960 had produced six computers.

FRANCE

Computer activity in France is proceeding at a moderate level, concentrated primarily in a few large, active firms. There is considerable potential for France to continue to be the leading producer of data processing equipment on the Continent, but it is clear that in the future there will be much more serious competition from other countries.

The six most active organizations in France are:

(1) Compagnie Des Machines BULL

(2) IBM France

(3) Société D'Electronique Et D' Automatisme (SEA)

(4) Société Nouvelle D'Electronique (SNE)

(5) Compagnie Générale de Télégraphie Sans Fil (CSF)

(6) Laboratoire Central de Télécommunications (ITT)

COMPAGNIE DES MACHINES BULL

BULL is the largest data processing manufacturing organization in Europe, and ranks among the top four companies in the world. With products ranging from small business machines to large-scale data processing systems, BULL exports 47 percent of its production to 34 countries. Its most important data processing equipments are the Gamma 3 and Gamma 60 computers, and the 300-DP series data processing systems.

Gamma 3

Gamma 3, a small-scale computer which when fully equipped is similar in size to the IBM 650, was introduced in 1952. About 850 of these computers have been delivered, 90 with magnetic drum memories. BULL is producing between 10 and 15 Gamma 3 systems each month.

Gamma 60

The Gamma 60 BULL's entry into the large-scale solid-state data processing system market, is an advanced machine featuring simultaneous independent processing of several unrelated problems. Gamma 60 is designed to accept a wide variety of input and output equipment, tailored to the needs of the particular installation.

The internal structure of Gamma 60 is based on the concept of autonomous operation of individual "elements": magnetic drum, arithmetic calculator, printer, etc., under control of a central unit. The latter contains a program distributor, a data distributor, and the high-speed memory. The central unit dispatches data and instructions to the elements and serves as a buffer storage for data transferred between elements. Assignments to elements are weighted according to established priority.

Four autonomous elements are available for data processing: an Arithmetic Calculator, operating on fixed or floating-point numbers of up to ten decimal digits plus sign (double-precision calculations can be programmed); a Logical Calculator which performs arithmetic operations on binary operands and carries out logical operations; a Generalized

Comparator, which executes one-way or two-way comparisons of variable length operands; and a Data Translator which (1) converts Gamma 60 internal code to external codes (for punched cards, tape, etc.), and vice versa, (2) edits data for the printer, and (3) rearranges data within a 24-bit word, or "catena," for optimum operation.

The core memory is built in stacks of 4096 27-bit words; the system can accommodate up to eight stacks. The additional three bits per word in the memory provide for a mod-7 catena check.

There are two 128-channel magnetic drums associated with the Gamma 60, storing 25,600 catenae each. The drums rotate at 300 rpm, record in the non-return-to-zero mode, and use diode-head switching with only one active data channel at a time.

Burroughs ElectroData magnetic tape transports will be used on the initial production systems until the BULL cartridge-loaded tape transport is available. The transports have been fitted with BULL 8-channel magnetic heads. Data is phase-recorded at 300 pulses per inch with a transverse parity bit, a mod-7 catena check and a longitudinal parity check. The tape speed is approximately 75 inches per second, yielding a 21.5-kc frame reading or writing rate.

The printer is a BULL design using 120 rotating printing wheels with 60 symbols per wheel. It operates at 300 lines per minute and contains two separate paper drives with independent controls and format skips.

The punched-card units are identical to the 300-cards-per-minute machines of the 300-DP series, described below.

The transistor-diode circuits of Gamma 60 are packaged in novel plug-in interconnected modules with hard wiring. These modules plug into diode cards. The computer uses about 24,000 transistors and 200,000 diodes.

In June 1960 the Gamma 60 engineering prototype was in final stages of system integration and debugging, with early programs being successfully run. There was a sizeable programming effort devoted to developing standard routines, compilers, and assemblers. As each of the major units of the system is completed it is shipped and installed on customers' premises. Final system integration, tests and the necessary retrofitting will be completed on site. In June 1960 three systems had been partially shipped and BULL plans to have five systems shipped by January 1961. Beginning in February 1961 one system per month will be shipped. There were 15 Gamma 60 systems on order in June 1960.

Plans to improve the Gamma 60 include faster arithmetic and memory units. After these improved elements are introduced the present units may continue to perform in the system for input-output data processing.

A 300-document-per-minute magnetic character recognition device using the BULL variable line code is under development.

300 DP Series

BULL has repackaged its conventional punched-card electro-mechanical equipment so that the printer, card reader, card punch, and arithmetic unit are each interconnected through a separate program control unit. All units operate at 300 cards per minute. Magnetic tape and magnetic drum units may be added as well as an electronic calculator to give an extremely flexible and versatile card system.

The program control unit uses a novel capacitor storage for temporary in-process data buffering.

IBM FRANCE

IBM France is the largest IBM World Trade Corporation activity in Europe. At a manufacturing facility near Paris IBM produces its familiar line of punched-card products and computing systems. Sales and service offices, showrooms, a service bureau and a development laboratory are located in Paris. A new laboratory is being built on the Riviera.

SOCIÉTÉ D'ELECTRONIQUE ET D'AUTOMATISME (SEA)

Primarily involved in the design and manufacture of analog computers for the military, SEA expanded into flight simulators and machine tool control. During the past four years the company has produced a series of digital computers for military, scientific and business applications. The computers are used almost entirely within France.

CAB 500

The CAB 500 is a serial digital computer used for scientific calculations. It was designed by SEA and is manufactured by the Schneider Group, a leading French electrical equipment company. Completely contained in a desk-size console, the CAB 500 uses magnetic logic elements (Symmag 200) and transistors, with magnetic drum storage. It is provided with electrical typewriter input-output, with optional tape punch and reader available. As of July, 1960, 15 CAB 500 machines had been sold and one delivered.

SEA 3000

The SEA 3000 system is a medium-scale data processor designed for scientific and commercial applications. The heart of the system is the SEA 3030 computer, a vacuum-tube, binary computer with ferrite core and drum memory. The system provides a broad variety of peripheral equipment, including both magnetic and paper tape input and output, a 900-lines-per-minute Sheppard printer, and a 2000-character-per-second cathode-ray tube photographic recorder.

SEA 3900

Successor to the 3000 is the SEA 3900, a fully transistorized serial-parallel 2-mc/second data processor also intended for general commercial applications. A modified version is available for scientific calculations. It is organized to achieve flexibility of peripheral equipment.

SOCIÉTÉ NOUVELLE D'ELECTRONIQUE (SNE)

SNE is marketing a parallel binary computer, the KL901, for scientific, statistical, and accounting applications. The vacuum-tube machine uses magnetic-tape and ferrite-core memories. The tape units have 36 tracks, allowing an entire word to be read in parallel. Up to eight tape units can be used. The core memory has a capacity of up to eight blocks of 1024 30-bit words, with a 5-μs access time. Input and output are via magnetic tape or punched paper tape (using a 1000-character-per-second paper tape reader).

COMPAGNIE GÉNÉRALE DE TÉLÉGRAPHIE SANS FIL (CSF)

CSF is one of the oldest and largest electronic equipment manufacturers in Europe. Founded in 1910, the company has over 15,000 employees, in 25 to 30 separate operations. CSF was formerly engaged almost entirely in military work, but in recent years has changed to about half military and half commercial activity. It is organized into four functional groups: Military, Civilian, Components, and Research.

CSF has been building military analog computers for over ten years. The company has recently developed some novel approaches to analog computation particularly in the high-frequency circuit field, and plans to enter the scientific general-purpose analog market. All computations are performed at a frequency of 500 kc/sec by modules that do not require inter-stage amplification since the transfer impedance is on the order of 50,000 ohms. The servo multiplier is transistorized and has a built-in converter

to derive 400-cps signals from the higher computation frequency for the servo motors. Each multiplier can drive up to six other multipliers.

Another unit of interest is a function generator using a spiral of flexible steel having 24 plunger-driven springs that deform the steel spiral to conform to the specific function to be generated. A differential transformer following the steel spiral detects the deformation and generates the function. The transformer has a precision of one part in ten thousand.

The company has been active in nuclear power control, process logging and control, and general industrial control applications. In conjunction with Intertechnique and Thompson-Ramo-Wooldridge, CSF has formed a new company known as "Compagnie Européenne d'Automatisme Electronique" to manufacture and market the R-W 300 computer and other control systems. CSF is also engaged in radar, communications and air traffic control systems.

LABORATOIRE CENTRAL DE TÉLÉCOMMUNICATIONS (ITT)

An ITT subsidiary, the Laboratoire Central de Télécommunications is active in electronic switching and telephone networks. Among its more interesting developments is a completely electronic 240-line telephone exchange, operating on an experimental basis at the company's Paris laboratory. This system uses neon tubes as switching elements, controlled by transistor-diode circuits.

Another ITT subsidiary in Paris, Le Matériel Téléphonique, is assisting Standard Elektrik Lorenz in the development of a reservation system for Air France.

OTHER FRENCH ACTIVITY

Many small companies throughout France manufacture components and peripheral equipment for data processing systems. In addition, some important basic research is being conducted at French Universities. Prominent among these is the University of Grenoble's Laboratoire de Calcul, headed by Professor J. Kuntzmann, regarded by many as the "father" of computing machinery in France. The Grenoble group is doing advanced work in machine translation of languages and numerical analysis.

ITALY

The application of computers in Italy is rapidly gaining momentum. As of June, 1960, nearly 150 computers were installed or on order (most of them from the United States), with about 85 in actual service. It is interesting to note that two-thirds of this equipment is for commercial banks or the manufacturing industries. Italian government agencies have followed the commercial companies in becoming interested in computer applications.

The earliest organizations using computers are the Digital Computing Center in Milan, founded in 1954 by Professor Luigi Dadda, and the Istituto Nazionale per le Applicazioni del Calcolo in Rome, directed by Professor Mauro Picone. The latter group is active in the field of numerical analysis and has been running a modified Ferranti Mark I computer (called FINAC) since 1955.

The most active computer development work currently being done is at the University of Pisa and the Olivetti Laboratories near Milan. These two groups are working on new computers as well as application problems. The University of Padua, Faculty of Statistics, is building a small drum computer.

In the field of machine language translation research, there is a project under way at the University of Milan under the direction of Dr. Sylvio Ceccato.

The Provisional International Computation Center in Rome provides educational and computational assistance to its members and/or UN bodies.

UNIVERSITY OF PISA (CENTRO STUDI CALCOLATRIC ELETTRONICHE)

The University of Pisa founded a computer center in 1955 with the objective of building a general-purpose digital computer and conducting research in the field. The center, under a committee from the department of Physics, Mathematics and Engineering, is directed by three men: Dr. A. Caracciola, and Messrs. Cecchini and Gerace. The work at the center embraces logical design, computer programming, and numerical analysis in one group and electronic design and construction is a second group. The computer development work is among the most advanced observed in Europe.

An 8-bit vacuum-tube/diode model of the computer was completed in 1957, based on d-c coupled asynchronous circuitry. The present computer, called CEP (Calcolatrice Elettronica Pisa), is a 36-bit parallel binary computer with a 4096-word magnetic core memory expandable to 32,768 words. The magnetic drum holds 16,384 words. Ampex magnetic tape units will be added in 1961.

The CEP has several interesting and advanced features:

1) A fixed high-speed memory for storing micro-programs, with a cycle time of 3 microseconds (operated in the laboratory down to 0.3 microseconds). The memory is identical in concept to the fixed memory being built at the University of Manchester for the MUSE computer, but is smaller. It consists of a 256 x 256 woven mesh of copper wire into which ferrite rods are placed (see details in part II). The fixed memory is operating in the CEP computer with a total of 228 micro-programs in use.

2) The order structure embodies double address modifiers rather than the conventional single modifier. The 36-bit word is subdivided as follows: 9 bits for instruction symbol, 6 bits first parameter modifier, 6 bits second parameter modifier, and 15 bits for memory address. The two 6-bit modifiers each identifying 1 of 64 index registers, permitting both index registers to be applied to the instruction, giving unusual flexibility and simplicity of programming. It is possible to generate 256 pseudo-instructions, extensive tables of jumps, and special subroutines for complex functions in the CEP. This design leads to flexibility at some cost in computer operating time.

3) An experimental high-speed adder similar in principle to the MUSE adder has been constructed. It has an additional time of 0.2 microseconds and may be retrofitted to the CEP later.

OLIVETTI

Olivetti is the only major commercial Italian manufacturing company extensively working on data processing equipment. This well established business machine company has been active in electronic computer development since 1956. It started by adapting its conventional line of key-driven office equipment to paper tape punches. The Olivetti tape punch makes six square holes per frame with no sprocket. There are already over 1000 accounting machines with paper tape punches sold in Italy. Olivetti has added a large series of converters to enable processing of the tape.

The tape-to-card converter operates at 6000 cards per hour and uses complete read-after-write checking. The card punch is an 80-column gang punch. The paper tape photocell reader operates at 800 characters per second and has a double reader for checking purposes. Over 45 tape converters had been sold by June, 1960.

The Olivetti high-speed printer operates at 600 lines per minute and is coupled to punched-card readers or magnetic-tape units.

One converter is capable of reading punched paper tape and converting it to magnetic tape, or reading magnetic tape to a high-speed printer. The converter has eight internal programs which may be defined by a plug board and selected by magnetic tape characters.

All of the converter equipment as well as the computers are designed from a standardized series of 100-kc transistor-diode logic modules, plug boards, chassis, racks and cabinets. The core memory modules have also been standardized for buffers and main memory.

The Olivetti computer product line includes two electronic systems: the ELEA 9003 and the ELEA 6001. The computers are both transistorized machines with variable word length. The 9003 is a large system for business applications, while the 6001 is a scientific computer. Both computers operate on a decimal character-by-character basis with memory access time of ten microseconds per character. These computers both use threaded-core type microprogramming.

The ELEA 9003 is the third computer of its type. One copy each was built of the prototypes, ELEA 9001 and 9002. There are orders for at least six ELEA 9003 computers and Olivetti plans to deliver three of these in 1960. Detailed characteristics of these computers are found in Section IV.

The Olivetti-BULL Sales Company markets the BULL line of punched-card equipment and the Gamma 3 and Gamma 60 computers in Italy. One Gamma 60 has been sold and a number of Gamma 3's are already in use.

Olivetti has established an electronics laboratory in Borgo Lombardo (near Milan) for the development and manufacture of electronic computers, adjuncts to the present business machine line, and punched-card, punched-tape and other converter equipment. Directed by Dr. Mario Tchou, the staff was formed from small groups of Olivetti scientists working at the University of Pisa and at the main Olivetti plant in Ivrea.

PROVISIONAL INTERNATIONAL COMPUTATION CENTER

In December 1951 a convention setting up an International Computation Center in Rome was drawn up by UNESCO. It is to take effect only when it has been ratified by ten countries. To date only seven--Belgium, Ceylon, France, Italy, Japan, Mexico and West Germany--have ratified the convention.

In September 1957, a Provisional International Computation Center was set up to begin to carry out the functions of the permanent center. Located in Rome, the provisional center is operated under a contract with the Istituto di Alto Matematica. Professor A. Ghizetti is responsible for administration of the center's activities.

The Provisional International Computation Center has been carrying on a number of useful activities, including the granting of a small

number of fellowships, publication of a bulletin, compilation and publication of an international glossary of computer terms, promotion of the use of modern techniques in gathering of the 1960 World Census of Agriculture, and the organization of symposia.

SWITZERLAND

There are no major manufacturers of electronic digital data processing equipment in Switzerland. There are, however, several excellent laboratories and numerous European offices of American firms, as well as computer activity in the universities and the Technische Hochschulen. The Swiss Federal Institute of Technology in Zurich appears to be the most active group in the digital computer field. They built a small drum machine called ERMETH in 1957, and have contributed to the development of ALGOL.

IBM RESEARCH LABORATORY

The IBM Research Laboratory in Adliswil-Zurich is the only branch of the research facilities of the U. S. IBM Corporation in Europe. The five other IBM laboratories in Europe (Stockholm, Sweden; Southampton, England; Paris, France; Amsterdam, Holland and Sindelfigen, Germany) are part of the IBM World Trade Corporation.

The Zurich laboratory, under the direction of Dr. A. P. Speiser, employs about 60 people, 20 of whom are scientists and engineers. They are presently housed in temporary quarters in suburban Zurich, awaiting the construction of a new laboratory due for completion in 1962. There are three prime areas of activity in the laboratory: magnetic thin films, hydraulic logic and advanced circuit techniques.

The magnetic thin film work is divided between two groups. One is engaged in metallurgical methods for depositing and heat treating reproducible, reliable ferromagnetic films. The other is concerned with measurements of the switching properties of the films and their application in logical devices and memory. Technical details are covered in part II.

Hydraulic logic, discussed in part II, uses miniature hydraulic elements to perform logical functions. The system appears particularly useful for industrial control applications. The IBM Zurich laboratory is doing advanced work in this field, and has developed operating elements and systems.

Circuit research has yielded a new core switch for magnetic core matrices and sub-microsecond core memories. The laboratory plans to study semiconductor properties for possible new applications.

CONTRAVES AG

The Contraves AG Company, located in Seebach-Zurich, has been manufacturing analog computers for many years. Contraves recently announced a new computer containing many electro-mechanical elements. Details were not available.

AUSTRIA

Computer activity in Austria is centered in the Institut fuer Niederfrequenztechnik, Technische Hochschule, Vienna. There a transistorized medium-scale digital computer was completed in May 1958 under the direction of Dr. H. Zemanek, and is being used for basic research in non-numerical applications, particularly the processing of logical data. The computer, called MAILÜEFTERL (gentle springtime breeze), was built to gain experience with computer circuits and to perform logical problems, rather than mathematics. It is being used as a translator for ALGOL in cooperation with the European ALGOL group, and for studying translation of natural languages. Mathematical problems are handled by an IBM 650 at the Technische Hochschule. Other general-purpose computers in Austria include a ZUSE-22 in Linz and a Sperry Rand Solid-State UNIVAC in Vienna.

The MAILÜEFTERL is being applied to learning by Drs. Zemanek and A. J. Angyan. They are studying conditioned reflex automatons and methods for computer simulation. The group is also investigating speech synthesis and analysis using the computer.

WESTERN GERMANY

The computer industry in Western Germany is quite active on many fronts, despite the country's relatively late start in the field. In the early 1950's the only significant work in computers was being done at the universities and research institutes; not until the past few years did the commercial companies become involved. Present-day commercial activity is centered primarily in four groups: Siemens & Halske AG, Telefunken, Standard Elektrik Lorenz AG, and Zuse KG. The technical institutes are currently active in advanced research and development. Of particular interest is work being done at the Karlsruhe Technische Hochschule on learning machines and character recognition, and the ALGOL development at the Institut fuer Angewandte Matematik (Institute for Applied Mathematics), at Johannes Gutenberg Universitaet in Mainz.

The European branches of IBM and Remington Rand are both very active in Germany. In fact, the first few UNIVAC Solid-State Computers were installed in Germany before they were even announced in the United States.

SIEMENS & HALSKE AG

The Siemens organization, founded 112 years ago, is the second largest company in Germany, with 186,000 employees. Siemens and its subsidiaries and affiliates are active in all phases of the electrical equipment industry. The Siemens & Halske AG specializes in communications, measuring and control equipment.

When Siemens decided to enter the computer field, they skipped the vacuum-tube stage and proceeded to develop a transistorized machine, the 2002. A prototype was operating in 1956 and a production model was completed in late 1958. The 2002 is a decimal machine, with magnetic-core and drum storage. Input-output equipment includes paper tape, punched card, magnetic tape printer and cathode-ray tube. The machine is designed for both scientific and commercial applications and sales have split evenly between these two uses. There were 18 Siemens 2002's on order in June, 1960, of which six had been delivered.

Siemens is an integrated company and manufactures as many components of the 2002 as possible, including transistors, diodes, resistors, cores, and capacitors. High-speed, automatically programmed inspection of all components was observed. The company also produces its own magnetic drums and has a high-speed printer under development. The construction work on the Siemens 2002 is some of the finest seen anywhere in Europe, and rivals the best American efforts. The printed-circuit cards are assembled with straight-line production methods; dip-soldering of the printed-circuit boards is done automatically with jet solder techniques.

Advanced research and development is underway in a very large new Central Laboratory facility. High-speed ferrite-core memories have been developed with cycle times less than 1.5 microseconds, operating over a wide temperature range. Research work is in progress on the deposition and measurement of magnetic thin films with promising results. High-speed switching transistors are also being perfected.

Siemens' other information processing activities encompass process control, mail-sorting equipment, automobile traffic control, and machine-tool control. Their applied programming work includes an assembly system called PROSA and a library of over 100 subroutines. They are also working on an ALGOL Translator for the 2002.

TELEFUNKEN

Telefunken, a wholly owned subsidiary of A.E.G. (Allgemeine Elektrizitaets-Gesellschaft), specializes in communications, radar, computers and other electronic fields. The parent company employs nearly 60,000 people, of which 21,000 are employed by Telefunken in various cities in Western Germany. There are two Telefunken plants engaged in computer activities, one in Backnang and the other in Konstanz. The Telefunken TR-4 computer is being designed and built at the Backnang facility, but will eventually be integrated with the Konstanz operation where the post office project and air traffic control work are done. Telefunken has transferred its magnetic tape recording group from Hamburg to Konstanz to develop a tape handling system for its computers.

The TR-4 is a large-scale high-speed computer designed for both business and scientific applications (see Section IV). It is the fastest computer being built in Germany; the electronic circuits use Telefunken ASZ-30 germanium drift transistors with an alpha cut-off between 100 and 150 megacycles. Five TR-4 systems were on

order as of June, 1960, with delivery of the first production model scheduled for October 1961. The prototype units appear very well designed and constructed; an interesting non-technical observation is that the TR-4 will be housed in a handsome wooden cabinet.

The most novel elements in this machine are the two fixed memories. One is a wired ferrite core array to store standard subroutines. E-shaped cores and keepers are used, in which one slot is a ONE and the other slot is a ZERO. Fifty-two cores with 52 diodes are mounted on a single board and 256 wires are threaded through the cores. Each board holds 256 words of storage with 1-microsecond access. Telefunken claims 30 percent cost saving using this technique as compared to coincident-current memory units.

The other fixed memory, used for micro-programming, consists of double-sided printed-circuit cards, with diodes inserted wherever connections are desired. Each micro-program step takes one clock cycle or 15 microseconds.

Telefunken is also designing the TR-5, a serial decimal computer with a clock frequency of only 50 kc. The TR-5, which will probably be built at Konstanz, is intended for the German Post Check applications currently under study there.

The German Post Check system is a nationwide system run by the post office supplementing the services of private banks and is found in many Western European countries. Telefunken was awarded a contract to

study the Post Check system with the objective of introducing electronic data processing. The government plans to use the standard ABA characters for checks, and Telefunken has developed a reader for the ABA system. Other phases of this program are in the preliminary planning stage.

Another development contract placed with Telefunken by the German government involves an air traffic control center, to be built around a Telefunken TR-4. Radar systems will supply information about traffic movements and various display and control consoles will allow human interrogation and control of plane movements.

Another major program at Telefunken's Konstanz facility is the development of automatic equipment for handling mail. Prototype models of a complete series of machines have been built and were demonstrated to German Post Office officials in June, 1960. Adopting a total systems approach to the program of mail handling, Telefunken has combined mechanical, pneumatic, electrical and electronic equipment into a completely automated postal facility.

After culling the parcel post and large envelopes from the letter-sized envelopes, the letter envelopes are faced and the stamps cancelled at a rate of six per second. The mail is then fed directly to the coding machines with appropriate intervening stacking. Operators at small consoles enter the destination of each letter into a keyboard and the envelope is marked with a flourescent four-digit, two-out-of-five code in the lower right corner of the envelope. The letters then pass

to the sorter where the fluorescent code is detected and the letter directed to the appropriate bin. The 6-letters-per-second sorter is built in 100-bin modules so that the system can be tailored to each post office's requirements.

OLYMPIA WERKE

Olympia Werke, another wholly owned subsidiary of AEG, is one of the largest manufacturers of typewriters and adding machines in Europe. The company has independently developed a small electronic computer for business purposes, designated OMEGA.

STANDARD ELEKTRIK LORENZ AG

Standard Elektrik Lorenz, an affiliate of the International Telephone and Telegraph Company, is primarily involved in telecommunications; however, with the growth of data processing, the Informatikwerk was formed in Stuttgart in 1957.

It is an ITT practice to assemble systems from equipment manufactured by its numerous companies. The Informatikwerk has designed and constructed several special-purpose computer installations for commercial applications. One of the first systems built was for a large mail-order store (Quelle). The result was a transistorized computer designed and built by Standard Elektrik Lorenz with special segregated memories for price and inventory, 50 input keyboard units and other special input-output units.

For the weight and balance project for SAS aircraft, a Santec ZEBRA computer from Standard Telephones and Cables Ltd. in England was combined with input-output equipment made by the German firm.

Standard Elektrik's first reservation system, in use since 1958, was for automobiles on the ferries between Germany and the Danish islands. Agents' sets located in the major cities interrogate the central computer to establish reservations. Reservation systems are currently being developed for two major airlines; these systems will maintain, in addition to seat reservations, lists of passengers' names and phone numbers.

Standard Elektrik Lorenz developed a transistorized general-purpose computer, the ER-56 (see Section IV); in June, 1960, five had been delivered and 15 were on order. A magnetic tape transport that handles data at the rate of 36,000 decimal digits per second with a tape speed of 2.5 meters per second has also been developed, and a new tape unit designated the K-10 (see Section II).

Other projects include research and development on character recognition, high-speed computer circuits, high-speed data transmission links and letter sorting equipment for post offices.

ZUSE KG

Dr. Konrad Zuse is one of the early pioneers in computer development in Germany. According to some European authorities, Dr.

Zuse was responsible for many important contributions to digital computation, but has not been given proper recognition. He formed his own company in the late 1940's; despite its modest size, the company is quite active and has sold more computers than any other German Manufacturer.

Zuse started developing computers in 1947 and produced the Z-4, a relay computer, in 1950. Another more advanced relay computer, the Z-5, appeared in 1953. In 1958 Zuse introduced a vacuum-tube 8192-word magnetic-drum computer, the Z-22. This is a medium-scale wired-core micro-programmed computer offering complete flexibility in programming. It has a paper-tape input, paper-tape and typewriter output and a minimum of external controls. Over 30 of these computers are installed in Europe.

In 1960 the Z-23 and Z-31 were announced. The Z-23 is a solid-state version of the Z-22, with an additional 240-word magnetic core memory. The Z-31 is a new, small, general-purpose solid-state computer with a basic magnetic core memory of 200 words, expandable to 10,000 words. It will also use paper tape as its input-output medium and a typewriter for printed output.

GERMAN TECHNICAL INSTITUTES

The Technische Hochschulen (technical colleges) in Munich, Darmstadt and Karlsruhe, the Max-Planck Institut fuer Physik in

Munich, and the Institut fuer Angewandte Matematik at the Johannes Gutenberg Universitaet in Mainz are responsible for most of the non-commercial computer research and development in Germany.

The Max-Planck Institut fuer Physik, formerly located in Goettingen and now in Munich, is primarily engaged in aerodynamic research. Computation needs in this field prompted the Institute to build Germany's first electronic computer, the G-1. Developed under the direction of Professor H. Billing, this vacuum-tube, magnetic-drum computer with paper tape input-output was completed in 1953. One year later a larger version with stored program, the G-2, was completed. The G-1, which was a temporary expedient to serve the institute while the G-2 was being completed, was retired in 1958. A third machine, G-3, is currently under development, due for completion in late 1960. The G-3 uses micro-programming and has a 4096-word 42-bit core memory. Magnetic tape units will be added later.

Advanced research at the Max-Planck Institut is concentrated on parametrons and thin films. Shortage of skilled manpower is restricting the progress of this work, which is not as advanced as that of other groups in Europe.

The Munich school is one of the earliest centers of computer activity in Germany, and is one of the early contributors to ALGOL (see part III). Work on PERM (Programmgesteuerte Elektronische Rechenanlage München) was started in 1950 under the direction of Professor H. Piloty. This pioneer German computer was completed in 1956 with a drum storage and limited input-output equipment. It is a parallel binary machine with both fixed and floating-point arithmetic operations. In 1959 a ferrite core storage unit was added and input-output equipment improved, with a resultant 30-fold increase in speed. The next project is to add magnetic tape.

Darmstadt was also the scene of early computer activity. The DERA computer was built there under the direction of Professor A. Walther. DERA is a decimal machine with drum and core storage, vacuum tube/diode circuitry, and BULL printer and card equipment. An IBM 650 was installed in 1957 to supplement DERA. Primarily a teaching center, Darmstadt had 350 students registered in a computer programming course in June 1960. Professor Walther has developed several unusual and clever training devices for teaching computer fundamentals.

At the Johannes Gutenberg Universitaet in Mainz, Professors Friedrich Bauer and Klaus Samelson are directing the development of ALGOL (see part III). They were among the early contributors to the ALGOL program. The Mainz group's main interests are mathematics and numerical analysis.

The Karlsruhe Institut Fuer Nachrichtenverarbeitung un Nachrichtenuebertragung (Institute for Information Processing and Information Communication) at Karlsruhe, directed by Professor K. Steinbuch (formerly of Standard Elektrik Lorenz) is the most active research group in Western Germany. Their work on learning machines, supported by government funds, is based on building hardware units rather than programming computers. Their objective is to develop equipment which exhibits behavior similar to a conditioned reflex in animals. One approach uses electrolytic cells for memory; another, a matrix of ferrite cores. In the latter case, conditioning consists of partial switching of the cores. After repeated partial switching, the cores are sensed and the output reaction appears as if due to a learning phenomenom (see part II).

Similar techniques are being applied to another project on pattern (character) recognition. The eventual aim is to "teach" the alphabet to the character recognition equipment. Although a long way from practical attainment of the ultimate goal, the work is one of the most interesting research developments in Europe. The institute has built equipment which automatically centers the letter image stored in what amounts to a two-dimensional shift register. The equipment also analyzes salient features of the letter image, such as location of ends of lines, existence of horizontal lines on top and bottom and whether the character opens up right or left. (See part II for more details.)

THE NETHERLANDS

Contributions in the information processing field from The Netherlands have been high for the total computer activity in the country. The major centers of work are: The Mathematisch Centrum, N. V. Electrologica, N. V. Philips, and the Netherlands Postal & Telecommunications Services. The general emphasis is on the smaller computer systems.

MATHEMATISCH CENTRUM

The Mathematisch Centrum was founded in 1946 as a government-sponsored non-profit organization to work in the fields of pure and applied mathematics, statistics and digital computers. Professor Dr. ir. A. van Wijngaarden joined the Centrum one year later and since then has been responsible for directing the efforts in computer design and application. In 1947 work was started on a relay computer, ARRA I, which was operational in 1951. This was followed by a magnetic drum computer, ARRA II, completed in 1953 and used for three years. A modified version of this computer, the FERTA, was built for the Fokker Airplane Works, Amsterdam, in early 1955 and is still in use.

The group then built the ARMAC (Automatische Rekenmachine Mathematische Centrum) which was completed in June 1956 and is still in operation.

In June 1958, under sponsorship of the Nillmij Insurance Company of Amsterdam, the transistorized magnetic-core X-1 computer was completed.

To fulfill the demands for additional X-1 computers Nillmij organized a new company -- N. V. Electrologica -- to make copies of the X-1 and to expand the computer's input-output capabilities. The engineering and fabrication group from the Mathematisch Centrum was transferred to the new company.

The Mathematisch Centrum's present staff of about 65 people concentrates on the application of ARMAC and X-1 to problems for government and industry. The Programming group, under the direction of Dr. D. W. Dijkstra, completed the ALGOL 60 translator for the X-1 in July 1960. They have also made significant contributions to problems in ship and dike design.

N. V. ELECTROLOGICA

N. V. Electrologica is an historical off-shoot of the Mathematisch Centrum of Amsterdam and is wholly owned by the Dutch Insurance Company, Nillmij. Messers. Loopstra and Scholten direct the technical activities of this three-year-old company that manufactures the X-1 computer (see section IV). The development work was completed by the Mathematisch Centrum and the engineering and fabrication group transferred to Electrologica to manufacture additional X-1 computers. The reliability of the computer has been improved and a large variety of peripheral equipment added. Programming is done under contract by the Mathematisch Centrum.

The X-1 is a 27-bit parallel, binary, single-address, magnetic-core-memory computer. It also has fixed (wired) core memory for subroutines

which may be added in 64-word units. Each 4096-word magnetic-core memory unit with integral read, write and address electronics may operate simultaneously with the peripheral equipment associated with it.

The X-1 computer has been well received in Europe. As of July, 1960, 14 computers were on order (six for the Netherlands and eight for Germany) and ten systems had been delivered.

N. V. PHILIPS GLOEILAMPEN FABRIEKEN

The Philips organization, one of the largest electrical component manufacturing companies in the world, has its main research and development laboratories in The Netherlands. To keep abreast of the new applications of components in computers, the company is building two computers for its own use. The computers will be installed in 1961 in a new computation center which will concentrate all administrative and scientific computation and the associated equipment into a single company center. The two Philips electronic computers, PASCAL and STEVIN (a famous Dutch accountant) were intentionally built well within the state of the art with vacuum tube, transistor, diode, magnetic core and magnetic drum techniques (see Section IV). They are identical except for input-output equipment.

In another laboratory, a complete line of transistorized building-block modules has been designed. Using these modules, Philips has assembled numerical control systems for machine tools, and a very small computer called MONA LISA.

Mullard, the Philips subsidiary in England, produces ferrite cores and memory stacks. One of the Mullard memories contains 4906 words, 50 bits per word, using two cores per bit, with a cycle time just under one microsecond.

Philips is also engaged in the design and construction of an electronic system for air traffic control. In June 1960 the gigantic digital data transmission system to be used for the United Airlines reservation system in the United States was nearing completion.

NETHERLANDS POSTAL AND TELECOMMUNICATIONS SERVICES

The Dr. Nehr Laboratory of the Netherlands Postal and Telecommunications Services, under the direction of Dr. ir. W. L. van der Poel, was responsible for the logical design of ZEBRA, an extremely simple and flexible digital computer. Standard Telephones and Cables Ltd., in England was responsible for the technical development and manufacture of the ZEBRA. (See Great Britain and Section IV for more details.)

SWEDEN

Sweden was the scene of some of Europe's earliest computer activity; e.g., a mechanical differential calculator was built by Georg and Edvard Scheutz and exhibited at the Paris Exposition in 1855. Today, Sweden is active in research, development and production. The work stems from the government's Swedish Board for Computing Machinery (Matematikmaskinnämnden), established in 1947 on the recommendation of Professor Stig Ekelof, who visited the ENIAC installation in 1946.

There are three major manufacturers of electronic data processing equipment in Sweden: Facit Electronics AB, ABN, and SAAB; all three companies have built complete systems. IBM World Trade Corporation and ITT maintain laboratory and manufacturing facilities in Sweden. In addition, a large number of foreign computers are installed in government, industrial and commercial organizations.

Research in machine translation of languages is currently underway at the Universities of Stockholm and Goteborg. Particular emphasis is placed on structural grammar and language statistics. One group is statistically analyzing punched tapes used in the United States to set type for books, using a Facit EDB computer.

SWEDISH BOARD FOR COMPUTING MACHINERY (MATEMATIKMASKINNÄMNDEN)

A board of five men and a council of twelve experts direct the activities of the Swedish Board, which has a staff of about 60. The Board

was initially set up in 1947 with a grant to buy or build a computer, and five men were sent to the United States for one year to learn computing techniques. Upon their return they undertook the construction of a relay computer, BARK, which was completed in 1950. While this computer was being completed, work was initiated on a vacuum-tube computer, BESK. Completed in 1953, BESK used a Williams tube memory, quite an advanced technique at that time; later the memory was replaced with a magnetic core store. The BESK was used as a pattern for the early machines built by Facit and SAAB, and by the Dansk Institut for Matematikmaskiner in Copenhagen.

BESK is a parallel 40-bit computer with magnetic core and drum storage. Originally equipped with paper tape input and electric typewriter output, the computer has been expanded in recent years to include punch tape output and magnetic tape units. Other recent improvements include higher speed (from 58 to 44 microseconds add time) and floating-point operation. (See details in Section IV.)

The BESK is in use at the Swedish Board's Computing Center (operating 24 hours a day since 1956), along with a Facit EDB2, installed in 1959, and an ALWAC IIIE given to the Board by Axel Wenner-Gren in 1958. The Facit computer is essentially a copy of the BESK, with larger core storage and a SAAB-built magnetic tape system using Ampex tape transports. A punched-card system is to be added in the near future.

The computers are operated on an open-shop basis with services for rent. From 1953 to 1960 1200 computing problems were processed, from

nuclear physics to highway earth moving problems. In addition to machine time rental, a programming service is provided, supported by a library of standard programs. An educational group gives courses in programming and data processing, and conducts seminars in numerical analysis, advanced programming, and programming theory.

Despite the development of computers within Sweden, the government has built a computing service agency almost entirely with computers of other countries. Several IBM 650 computers are currently in use, along with three Ferranti systems. A Ferranti ORION and several IBM solid-state computers are on order.

FACIT

FACIT Electronic AB, a subsidiary of FACIT-Atvidabergs, is one of Sweden's major data processing equipment manufacturers. Its entry into electronic data processing was prompted in 1956, when a group of engineers left the Swedish Board for Computing Machinery and joined FACIT. Data processing activities are conducted at a new and very elegant engineering and laboratory facility in suburban Stockholm.

The FACIT EDB computer is an almost exact copy of the BESK computer developed by the Swedish Board. About ten of these medium-scale vacuum-tube machines have been produced and sold. The first machine produced is installed in a data processing center in Stockholm established and maintained by the company, providing computing service on a rental basis. The current model, the EDB3, incorporates the new Facit ECM 64 Carousel memory.

paper tape input and output, BULL punched card input and output, and IBM type 407 line printer output. Provision is made for connecting up to 64 Carousel units, plus additional external core memories for handling large quantities of data.

The most significant work being done by FACIT is in the area of input-output equipment. Two unique developments in this area are a dielectric paper tape reader which reads 500 characters per second and starts and stops on one character, and the Carousel tape unit, described in Section II.

Although currently restricting its marketing activities to Europe, FACIT negotiated with an American firm, the Autonetics Division of North American Aviation, to manufacture and market FACIT-designed peripheral equipment in the United States, Canada, and Mexico.

ABN

Aktiebolaget Bo Nyman is a relatively new Swedish industrial group founded and owned by B. K. G. Nyman. The company has three factories, one of which, situated in central Sweden, manufactures trams, railway cars, digging machines, and mechanical parts for magnetic drums. At the other two factories, located near Stockholm, about 300 persons are engaged in the manufacture of telephone equipment, intercommunication systems, and data processing equipment.

ABN entered the data processing field in 1953, building paper tape readers and punches. Nyman bought out the ALWAC computer interests from Axel Wenner-Gren and is currently manufacturing a modified and improved version of the ALWAC IIIE computer as the Wegematic 1000. Five of these

medium-scale vacuum-tube computers have been shipped to date; 13 have been sold, and a total production of 20 is planned. ABN intends to replace the recirculation drum memory with a 128-word magnetic core memory in future machines. It is also planned to replace the Flexowriter with ABN-built tape readers and punches.

ABN has decided to concentrate on special-purpose devices and peripheral equipment, rather than large-scale systems. Manufacture of a magnetic tape unit similar to the ALWAC mechanism is planned for the near future. This unit will provide seven data channels plus one check channel, and will operate at 100 inches per second at 100 characters per inch, with a 10-millisecond start-stop time. It will use transistors and tubes, and will have a tape control search feature similar to the ALWAC unit.

An example of the type of special-purpose devices produced by ABN is the Addo-Matic, a combination of a magnetic drum memory and an Addo-X accounting machine. The drum has a 5000-word capacity, each word containing 14 decimal figures plus signs. Several drum systems and paper tape equipment can be used with one accounting machine.

SAAB

SAAB, a large Swedish industrial group well known for its aircraft and automobile production, is also active in digital computation. The company built a BESK-type computer for its own use, and designed and built transistorized tape control equipment for both the original BESK and the SAAB copy. The company has built a transistorized airborne computer, and was investigating the feasibility of marketing a version of this computer for commercial applications.

DENMARK

In 1953 the Academy of Sciences in Denmark formed a new institute, Regnecentralen (Dansk Institut for Mathmatikmaskiner), to work in the field of digital computer development and application. There are over 20 such institutes affiliated with the Danish Academy. They may perform work for any governmental, industrial or commercial organizations and may reinvest any surplus funds in more advanced equipment or research.

REGNECENTRALEN

Regnecentralen, under the direction of Dr. Niels Ivar Bech, is the only group in Denmark actively engaged in the design and fabrication of electronic digital computers. The group decided to pattern its first computer, the DASK, after the BESK computer designed by the Swedish Board for Computing Machinery. After an intensive study period and the addition of certain order code modifications and three index registers to the machine design, the DASK was built and put into around-the-clock operation in early 1958. The computer initially used punched paper tape input and output, punched cards and magnetic tape were added in 1959, using transistor circuits. The programming staff planned to complete the ALGOL 60 Translator for DASK in October 1960.

Regnecentralen, in connection with computing and consulting work for the Geodetic Institute of Denmark, was requested to design and build a new computer for the Institute. This computer, GEIR, (Geodetic Institute Electronic Computer) was observed in the final assembly stages, scheduled

to be in operation by the end of 1960. The GEIR is a transistorized classical parallel computer with a 1024-word magnetic core storage and a 12,000-word drum storage. The instruction work is made up of a 10-bit address, a 10-bit increment, a 14-bit operation code, a 6-bit indicator modifier and the increment for relative addressing. The computer was planned for considerable programming flexibility and simplicity. (See Section IV.)

It is anticipated that six models of GEIR will be built by Regnecentralen for Danish universities and other governmental organizations. An ALGOL 60 Translator is planned for the GEIR.

In addition to the above computers, Regnecentralen has ordered a Telefunken TR-4, due for delivery in 1961. The programming staff is busy developing programs and compilers for this new computer.

An extensive operations research effort is also being carried out by the Institute. They are currently doing work in the field of genetics, food consumption, production scheduling, transportation scheduling and traffic analysis, with a competent staff of economists, statisticians, mathematicians and programmers.

COMPUTER COMPARISONS

The tables which follow this section present a comprehensive comparison of all of the major European computers and data processing systems. The data in the tables were derived through careful analysis of manufacturer's information, and, in most cases, were verified by the manufacturers through their review of the completed tables. The criteria chosen for the presentation are believed to represent the most accurate indices for effecting a meaningful comparison of similar systems. Table II lists the definitions of these indices.

TABLE II - DEFINITION OF EUROPEAN COMPUTER CHART TERMINOLOGY

Term	Definition
Manufacturer and Country	This is the actual manufacturing concern. In some cases the agency responsible for the design or sales of the machine, may be shown in parentheses. Intra-company divisions are shown where appropriate. The country is where the computer is actually built. If it is built in more than one country, the country of first origin is given with the others in parenthesis.
Computer Name	This is the name the computer is usually called. For numbered computers, the manufacturers abbreviation is usually shown along with the number.
Availability--Number on Order	This is the total number of machines for which firm orders have been received, but which have not been installed. The figure should be current as of September 1960.
Availability--Number Installed	This is the number of completed machines actually installed and operating as of September 1960.
Availability--Date of First Installation	This is the actual (or anticipated) date of first installation.
Technique--Circuits	Transistor, transistor-diode, transistor-core, vacuum tube.
Word Length	The number of bits (including sign) or digits used in a normal add operation. Parity bits are not included in the count. In variable word length machines, the number of digits or characters retrieved from memory on each cycle is indicated.
Addresses per Instruction/ Instructions per Word	The numerator is the number of full addresses in the instruction used to specify operands. In those machines where an address is included in each instruction to specify the location of the next instruction, the form x + 1 is used for an x address machine

TABLE II - DEFINITION OF EUROPEAN COMPUTER CHART TERMINOLOGY (Cont'd)

Term	Definition
Number of Operations: Decoded/Possible	The numerator is the number of operation codes with assigned functions. The denominator is the number of combinations possible of the bits (or digits) used to specify the operation code.
Operation Times	All operation times are in microseconds. The times include memory access for the instruction and the operands. Indicate by "Subroutine" where a single instruction cannot perform the operation.
Storage-Cycle Time	The minimum time between two consecutive access to the same storage unit. This involves the read and restore cycle on core memories.
Storage-Time/Access-Time	The average time to retrieve one word. This is the read cycle only on core memories, and half the time of a drum revolution on drum memories.
Storage--Data Unit Accessed	This is the amount of information transferred out on one call to the memory. This is usually a word, but sometimes it is a character (variable word length machines) on a block of many words (back up drum and memories).
On-Line Input-Output--Speed	The speed of various units is rated as follows: Punch card equipment: Cards per minute. Paper tape equipment: Frames per second. Line printers: Lines per minute. Other units: Characters per second.
On-Line Input-Output--Number of Units	This is the maximum number of units which may be attached to a production model computer without modifying the equipment.
Magnetic Tape--Characters per Second	Alphanumeric character or six bit groups transferred per second. This is the maximum transfer rate within a block.

TABLE II - DEFINITION OF EUROPEAN COMPUTER CHART TERMINOLOGY (Cont'd)

Term	Definition
Magnetic Tape--Bits per Inch/ Inches per Second	Bits per inch on each track.
Magnetic Tape--Number of Units Operating/Total Tape Units	The numerator refers to the number of tape drives which may be reading (or writing) data into the central computer simultaneously. Rewinding, searching or other independent operations are not considered.
Special Features	Any important facts about the computer which are not shown elsewhere on the chart.

EUROPEAN COMPUTERS

MANUFACTURER AND COUNTRY	COMPUTER NAME	AVAILABILITY: NUMBER ON ORDER	AVAILABILITY: NUMBER INSTALLED	AVAILABILITY: DATE OF FIRST INSTALLATION	TECHNIQUE: CIRCUITS	TECHNIQUE: CLOCK RATE	GENERAL MACHINE FEATURES: WORD LENGTH	ADDRESSES PER INSTRUCTION / INSTRUCTIONS PER WORD	NUMBER OF OPERATIONS / DECODED POSSIBLE	NUMBER OF INDEX REGISTERS	INDIRECT ADDRESSING	PARTIAL AND MULTIPLE WORD OPERATIONS	INTERNAL CHECKING	OPERATION TIMES (MICRO-SECONDS) (INCLUDING MEMORY ACCESSES): ADDITION (FIXED / FLOATING)	MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	TYPE OF STORAGE	NUMBE[R] MINIMUM SYSTEM
LEO COMPUTERS LTD GREAT BRITAIN	LEO III	3	0	1961	TRANSISTOR DIODE	INA	42 BITS	1/2	110/140	UP TO 12	NO	HALF WORD OPERATIONS	PARITY	44 / 200-450	300-700 / 600-900	30/49	56/88	CORE	024
FERRANTI LTD GREAT BRITAIN	PEGASUS	10	28	1956	VACUUM TUBE	333 KC	39 BITS	1/2	62/64	7	NO	DOUBLE WORD	PARITY	300 / SUBROUTINE	1800 / SUBROUTINE	300/300	425/2750	NICKEL DELAY LINE DRUM	55 7 68
FERRANTI LTD GREAT BRITAIN	MERCURY	3	19	957	VACUUM TUBE	000 KC	0-20 40 BITS	1/2	70/8	7	NO	DOUBLE WORD	PARITY	60/30	SUBROUTINE / 300	60/60	60/300	CORE DRUM	024 8192
FERRANTI LTD GREAT BRITAIN	PERSEUS	0	2	1958	VACUUM TUBE	333 KC	72 BITS	1/3	63/64	7	NO	BOTH	PARITY AND COMPLETE ARITHMETIC CHECK	234 / SUBROUTINE	1780 / SUBROUTINE	234/3744	234/4680	NICKEL DELAY LINE	024
FERRANTI LTD GREAT BRITAIN	SIRIUS	2	1	959	TRANSISTOR CORE	500 KC	0 DECIMAL DIGITS	1/1	60/00	[illegible]	NO	NO	PARITY	240 / SUBROUTINE	4000-[illegible]000 / SUBROUTINE	240/4000	240/1200	NICKEL DELAY LINE	1000
FERRANTI LTD GREAT BRITAIN	ARGUS	0	1	1960	TRANSISTOR DIODE	500 KC	2 BITS	1/1	54/64	7	NO	DOUBLE WORD	PARITY	20 / SUBROUTINE	100 / SUBROUTINE	20/20	20/20	CORE DRUM	024 0
FERRANTI LTD GREAT BRITAIN	ORION	9	0	961	TRANSISTOR CORE	500 KC	48 BITS	3/1	4/128	64	YES	BOTH	PARITY	36-68 / 60-80	64-184 / 40-160	36/68	4/48	CORE DRUM	4096 6384
FERRANTI LTD GREAT BRITAIN	APOLLO	1	0	1961	TRANSISTOR DIODE	500 KC	24 BITS	1/1	50/28	3	NO	NO	PARITY	6 / SUBROUTINE	60 / SUBROUTINE	6/12	9/30	CORE	8000

INA - INFORMATION NOT AVAILABLE

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OPEAN COMPUTERS

ON TIMES (MICRO-SECONDS) (…NG MEMORY ACCESSES)			STORAGE							ON-LINE INPUT-OUTPUT				MAGNETIC TAPE				SPECIAL FEATURES	COMPUTER NAME
MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE AVERAGE)	TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	NUMBER OF WORDS: MAXIMUM SYSTEM	NUMBER OF WORDS: MODULE SIZE	WORD TIME μ SEC	ACCESS TIME μ SEC	DATA UNIT ACCESSED	TYPE OF UNIT	MANUFACTURER	SPEED	NUMBER OF UNITS	MANUFACTURER	CHAR PER SECOND	BITS/INCH / INCHES/SEC	NUMBER OPERATING / TOTAL TAPE UNITS		
300-700 / 600-900	30 / 49	56 / 88	CORE	1024	32,768	4096	[illegible]	7	WORD OR HALF WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	ELLIOTT TELETYPE ICT IBM/ICT ANALEX ICT IBM	1000 FPS 110 FPS 600 CPM 250/100 CPM 850 LPM 600 LPM 150 LPM	32 48 6 32 16	AMPEX (1") AMPEX (½)	30,000 45,000	300 / 50 300 / 150	3 / 24 4 / 32	THE COMPUTER WILL GENERATE OUTPUT LAYOUT AUTOMATICALLY. A SINGLE INSTRUCTION WILL FOLLOW A TABLE OF ADDRESSES AND EDITING CONTROLS TO A PERFECT OUTPUT LINE.	LEO III
1900 / SUBROUTINE	300 / 300	425 / 2750	NICKEL DELAY LINE DRUM	55 7168	55 7168	— —	[illegible] [illegible]	 8000	WORD WORD OR 8 WORDS	TAPE READER TAPE PUNCH CARD READER CARD PUNCH	FERRANTI TELETYPE POWER SAMAS POWER SAMAS	300 FPS 60 FPS 200 CPM 100 CPM	2 1 1 1	BURROUGHS OR DECCA	3,250	123 / 75	2 / 10	7 ACCUMULATORS	PEGASUS
SUBROUTINE / 300	60 / 60	60 / 300	CORE DRUM	1024 8192	1024 16,384	— 4096	10 [illegible]	2 10,000	WORD 32 WORDS	TAPE READER TAPE PUNCH 7 OTHERS OPTIONAL	FERRANTI CREED	300 FPS 33 FPS	2 1	BURROUGHS	15,000	266 / 60	2 / 8	DIVISION BY SUBROUTINE ONLY	MERCURY
780 / SUBROUTINE	234 / 3744	234 / 4680	NICKEL DELAY LINE	1024	1024	—	234	234	WORD	TAPE READER CARD READER TELE-PRINTER	FERRANTI POWER SAMAS CREED	200 FPS 300 CPM 10 CPS	2 1 1	BURROUGHS	3,250	123 / 75	4 / 16	VARIABLE RADIX ARITHMETIC OPERATIONS	PERSEUS
4000-6000 / SUBROUTINE	240 / 4000	240 / 100	NICKEL DELAY LINE	1000	10,000	100	50	4000	WORD	TAPE READER TAPE PUNCH	FERRANTI TELETYPE	300 FPS 60 FPS	10 10	MAGNETIC TAPE AVAILABLE				—	SIRIUS
100 / SUBROUTINE	20 / 20	20 / 20	CORE DRUM	1024 [illegible]	3072 50,000	1024 50,000	20 4	2 2,000	WORD TRACK	CUSTOM SPECIFIED (INCLUDES ANALOG-DIGITAL CONVERTERS)				CUSTOM SPECIFIED				PROCESS CONTROL MACHINE WITH PEG BOARD INSTRUCTIONS	ARGUS
64-184 / 40-160	36 / 68	4 / 48	CORE DRUM	4096 16,384	16,384 16,777,216	4096 16,384	[illegible] 200	[illegible] 2,000	WORD VARIABLE	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	FERRANTI CREED ICT ICT ICT BULL RANK	1000 FPS 300 FPS 600 CPM 100 CPM 300, 135 3000 LPM	NO LIMIT	AMPEX FR 300	90,000	375 / 120	4 / 16	—	ORION
60 / SUBROUTINE	6 / 12	8 / 30	CORE	8000	32,000	4000	6	2	WORD	CUSTOM SPECIFIED (INCLUDES ANALOG-DIGITAL CONVERTERS)				CUSTOM SPECIFIED				PRIMARILY FOR AIR TRAFFIC CONTROL	APOLLO

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AUERBACH Electronics Corporation
Philadelphia, Pennsylvania

EUROPEAN COMPUTERS

MANUFACTURER AND COUNTRY	COMPUTER NAME	AVAILABILITY: NUMBER ON ORDER	AVAILABILITY: NUMBER INSTALLED	AVAILABILITY: DATE OF FIRST INSTALLATION	TECHNIQUE: CIRCUITS	TECHNIQUE: CLOCK RATE	GENERAL MACHINE FEATURES: WORD LENGTH	ADDRESSES PER INSTRUCTION / INSTRUCTIONS PER WORD	NUMBER OF OPERATIONS DECODED / POSSIBLE	NUMBER OF INDEX REGISTERS	INDIRECT ADDRESSING	PARTIAL AND MULTIPLE WORD OPERATIONS	INTERNAL CHECKING	OPERATION TIMES (MICRO-SECONDS) (INCLUDING MEMORY ACCESSES): ADDITION (FIXED / FLOATING)	MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	TYPE OF STORAGE	NUMB[ER] MINIMUM SYSTEM
FERRANTI LTD AND MANCHESTER UNIVERSITY GREAT BRITAIN	MUSE (ATLAS)	1	0	1961	TRANSISTOR DIODE	INA	48 BITS	1 / 1	400 ANTICIPATED / 024	125	NO	BOTH	PARITY	1.1 / 1.1	4 / 4	1 / 2	1 / 12	CORE DRUM	8 32 0
ELLIOTT BROTHERS GREAT BRITAIN	803	18	5	959	TRANSISTOR	166.5 KC	39 BITS	1 / 2	40 / 64	4096	NO	NO	PARITY	720 / 720	23,500 / 3360	720 / 720	1440 / 15,480	CORE	4096
ELLIOTT BROTHERS GREAT BRITAIN	503	0	0	1962	TRANSISTOR	INA	39 BITS	1 / 2	INA / 64	4096	NO	INA	PARITY	8 / 5-15	18-28 / 15-25	4 / 4	INA	CORE	4096
EMI ELECTRONICS LTD GREAT BRITAIN	EMIDEC 1100	15	4	1960	TRANSISTOR	100 KC	36 BITS	1 / 1	30 / 32	7	NO	DOUBLE WORD ADDITION	NONE	140 SUBROUTINE	1260 SUBROUTINE	25 / 225	170 / 340	CORE DRUM	1024 16,384
EMI ELECTRONICS LTD GREAT BRITAIN	EMIDEC 2400	1	0	1961	TRANSISTOR DIODE	500 KC	36 BITS	1 / 1	51 / 64	64	NO	MULTI WORD TRANSFERS	PARITY	12 SUBROUTINE	130 SUBROUTINE	16 / 30	32 / 60	CORE DIODE-CAPACITOR	4096 64
ICT GREAT BRITAIN	ICT 1200 ICT 1201 ICT 1202	21	57	955	VACUUM TUBE	40 KC	40 BITS	1 + 1 / 1	24 / 64	0	NO	BOTH	NO	2500 SUBROUTINE	20,000 SUBROUTINE	1250 / 20 000	2500 / 2500	DRUM	4096
COMPUTER DEVELOPMENT LTD (ICT & GEC) GREAT BRITAIN	ICT 301	25	0	1961	TRANSISTOR DIODE	300 KC	12 DECIMAL OR STERLING DIGITS INCL SIGN	1 / 2	51 / 00	0	NO	NO	2 PARITY BITS PER WORD CHECK SUM ON DRUM	7 SUBROUTINE	1040 SUBROUTINE	2 / 12	23 / 23	CORE DRUM	400 2 000
STANDARD TELEPHONES AND CABLES GREAT BRITAIN	STANTEC ZEBRA	6	32	1957	VACUUM TUBE	30 KC	33 BITS	1 / 1	MICRO PROGRAMMED / 2^{15}	2	NO	MULTIPLE WORD OPERATIONS	PARITY	312 SUBROUTINE	11,000 SUBROUTINE	INA	INA	DRUM	8192

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...OPEAN COMPUTERS

...N TIMES (MICRO-SECONDS) ...G MEMORY ACCESSES)			STORAGE							ON-LINE INPUT-OUTPUT				MAGNETIC TAPE				SPECIAL FEATURES	COMPUTER NAME
MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	NUMBER OF WORDS: MAXIMUM SYSTEM	NUMBER OF WORDS: MODULE SIZE	WORD TIME μ SEC	ACCESS TIME μ SEC	DATA UNIT ACCESSED	TYPE OF UNIT	MANUFACTURER	SPEED	NUMBER OF UNITS	MANUFACTURER	CHAR PER SECOND	BITS/INCH / INCHES/SEC	NUMBER OPERATING / TOTAL TAPE UNITS		
4 / 4	1 / 1	1 / 12	CORE DRUM	8192 0	262,144 (A) 1,048,576 (A)	4096 24,576	2 4	0.5 6000	WORD 512 WORDS	CUSTOM SPECIFIED			256 TOTAL	AMPEX	90,000	375 / 120	8 / 32	AUTOMATIC DRUM-CORE DATA TRANSFERS FIXED FERRITE SLUG MEMORY FOR CONTROL OPERATIONS	MUSE (ATLAS)
[illegible]0,500 / [illegible]	720 / 720	440 / 5,480	CORE	4096	8192	4096	INA	INA	WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH 35 MM MAG FILM ANALOG-DIGITAL CONVERTERS	ELLIOTT CREED ELLIOTT IBM ELLIOTT	40 FPS 25 FPS 300 CPM 100 CPM 1.44 MSEC PER WORD	INA	NO MAGNETIC TAPE				SERIAL COMPUTER	803
18-28 / 15-25	4 / 4	INA	CORE	4096	8192	INA	4	INA	WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	ELLIOTT TELETYPE ELLIOTT IBM INA	1000 FPS 100 FPS 400 CPM 100 CPM 600 LPM	MULTIPLE MULTIPLE MULTIPLE MULTIPLE MULTIPLE	POTTER	45,000	INA	INA	PROGRAMS COMPATIBLE WITH 803	503
1260 / SUBROUTINE	25 / 225	170 / 540	CORE DRUM	[illegible]24 16,384	4096 65,536	— 16,384	[illegible] INA	[illegible] 5000	WORD 4 WORDS	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	FERRANTI CREED ELLIOTT ICT ICT	300 FPS 30/300 FPS 400 CPM 100 CPM 300 LPM	6 TOTAL	AMPEX FR 300	20,000	167 / 120	6 / 16	AUTOMATIC DECIMAL-BINARY CONVERSIONS	EMIDEC 1100
130 / SUBROUTINE	6 / 30	[illegible] / 60	CORE DIODE CAPACITOR	4096 64	32,768 64	4096 —	10 4.5	5 1.5	WORD WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	ELLIOTT CREED ELLIOTT ICT ICT RANK	1000 FPS 300 FPS 400 CPM 100 CPM 300 LPM 3000 LPM	MULTIPLE MULTIPLE MULTIPLE MULTIPLE 6	EMI	60,000	300 / 200	5 / 30	FLEXIBLE SWITCHING OF PERIPHERAL EQUIPMENT TO ON-LINE OR OFF-LINE USE PROGRAM INTERRUPT	EMIDEC 2400
20,000 / SUBROUTINE	250 / 20,000	2500 / 2500	DRUM	4096	8192	4096	250	[illegible]	WORD	CARD READER CARD PUNCH PRINTER	ICT ICT ICT	[illegible] CPM 100 CPM 100 LPM	1 1 1	NO MAGNETIC TAPE				DIRECT TRANSFER FROM CARD READER TO PRINTER AND PUNCH. THE SAME CARD CAN BE PUNCHED IN BOTH DECIMAL AND BINARY	ICT 1200 ICT 1201 ICT 1202
[illegible]040 / SUBROUTINE	2 / 12	23 / 23	CORE DRUM	400 12,000	2000 96,000	400 12,000	[illegible] 52	4 .86	WORD 400 WORDS	CARD READER CARD PUNCH PRINTER	ICT ICT ICT	600 CPM 100 CPM 600 LPM	1 1 1	AMPEX FR 300 AMPEX FR 400	90,000 22,500	300 / 150 300 / 75	2 / 8	AUTOMATIC ERROR CORRECTION ON TAPES	ICT 1301
[illegible],000 / SUBROUTINE	INA	INA	DRUM	8192	8192	—	312	5000	WORD	TAPE READER TAPE PUNCH TELE-PRINTER	FERRANTI TELETYPE CREED	200 FPS 50 FPS 7 CPS	1-2 1-2 1-2	NO MAGNETIC TAPE				MICRO-PROGRAMMED COMPUTER	STANTEC ZEBRA

(A) MAXIMUM INTERNAL MEMORY ADDRESSING CAPACITY IS 1,048,576 WORDS

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AUERBACH Electronics Corporation
Philadelphia, Pennsylvania

EUROPEAN COMPUTERS

MANUFACTURER AND COUNTRY	COMPUTER NAME	AVAILABILITY: NUMBER ON ORDER	AVAILABILITY: NUMBER INSTALLED	AVAILABILITY: DATE OF FIRST INSTALLATION	TECHNIQUE: CIRCUITS	TECHNIQUE: CLOCK RATE	GENERAL MACHINE FEATURES: WORD LENGTH	ADDRESSES PER INSTRUCTION / INSTRUCTIONS PER WORD	NUMBER OF OPERATIONS DECODED / POSSIBLE	NUMBER OF INDEX REGISTERS	INDIRECT ADDRESSING	PARTIAL AND MULTIPLE WORD OPERATIONS	INTERNAL CHECKING	OPERATION TIMES (MICRO-SECONDS) (INCLUDING MEMORY ACCESSES): ADDITION (FIXED / FLOATING)	MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	S… TYPE OF STORAGE	NUMBER … MINIMUM SYSTEM	MAX… SYS…
STANDARD TELEPHONES AND CABLES GREAT BRITAIN	STANTEC SYSTEM	10	0	1960	TRANSISTOR	128 KC	33 BITS	1 / 1	MICRO PROGRAMMED / 2^{15}	12	NO	MULTIPLE WORD OPERATIONS	PARITY	312 / SUBROUTINE	624 / SUBROUTINE	INA	INA	CORE DRUM	512 8192	81… 81…
ENGLISH ELECTRIC GREAT BRITAIN	DEUCE	2	30	1955	VACUUM TUBE	1000 KC	32 BITS	2 + 1 / 1	NOT DEFINED	0	NO	MANY DOUBLE WORD OPERATIONS	NO	64 / SUBROUTINE	2080 / SUBROUTINE	64 / 96	64 / 544	MERCURY DELAY LINE DRUM	402 8192	6… 81…
ENGLISH ELECTRIC GREAT BRITAIN	KDF-9	INA	0	1962	TRANSISTOR CORE DIODE	1000 KC	48 BITS	0 OR 1 / 2 TO 6	292 / INA	16	YES	DOUBLE WORD	INA	1 / 7 FROM SPECIAL WORKING STORE	14 / 14	INA	2.5 / 5	CORE	4096	32,…
COMPAGNIE DES MACHINES BULL FRANCE	GAMMA 3 ET	25	88	[illegible]	VACUUM TUBE DIODE	280 KC	12 DIGITS (BINARY COMMANDS)	1 / 3	INA	0	NO	VARIABLE WORD LENGTH UP TO 12 DIGITS	INA	850 / SUBROUTINE	11,000 / SUBROUTINE	INA	INA	ELECTRO-MAGNETIC DELAY LINE DRUM	71 4096	1… 16,3…
COMPAGNIE DES MACHINES BULL FRANCE	GAMMA 60	13	3	1960	TRANSISTOR DIODE	2700 KC	6 DIGITS OR 24 BITS	1 - 3 / UNDEFINED	INA	0	YES	NO	MODULO 7 CHECK ON ALL OPERATIONS	100 / INA	250 / INA	INA	INA	CORE DRUM	8192 25,600	32,… N… LI…
SEA FRANCE	CAB 3030	INA	3	1958	VACUUM TUBE DIODE	100 KC	30 BITS	2 / 1	31 / 31	1	NO	DOUBLE WORD	PARITY	320 / 9600	640 / 5120	INA	320 / 5120	CORE DRUM	1024 16,384	16,… 16,…
LE MATÉREL ELECTRIQUE S-W (SEA) FRANCE	CAB 500	20	2	1960	MAGNETIC SWITCHING (SYMMAG)	220 KC	32 BITS	2 / 1	46 / 64	1	NO	DOUBLE WORD	PARITY	308 / SUBROUTINE	SUBROUTINE / SUBROUTINE	INA	308 / 308	DRUM SHIFT REGISTER	16,384 16	16,…
SEA FRANCE	SEA 3900	20	2	INA	TRANSISTOR DIODE	2000 KC	VARIABLE (2 CHARACTERS PER MEMORY ACCESS)	3 / UNDEFINED	43 / 128	3 (ONE FOR EACH ADDRESS)	NO	DATA CONTROLLED WORD LENGTH	PARITY	216 / SUBROUTINE [5 DIGIT FACTORS]	5590 / SUBROUTINE	48 / 48	UNDEFINED	CORE DRUM	2048 CHARACTERS 40,960 CHARACTERS	4… CHAR… 81… CHAR…

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…PEAN COMPUTERS

… TIMES (MICRO-SECONDS) MEMORY ACCESSES)			STORAGE							ON-LINE INPUT-OUTPUT				MAGNETIC TAPE				SPECIAL FEATURES	COMPUTER NAME
…ULTIPLY FIXED / …LOATING	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	NUMBER OF WORDS: MAXIMUM SYSTEM	NUMBER OF WORDS: MODULE SIZE	WORD TIME μ SEC	ACCESS TIME μ SEC	DATA UNIT ACCESSED	TYPE OF UNIT	MANUFACTURER	SPEED	NUMBER OF UNITS	MANUFACTURER	CHAR PER SECOND	BITS/INCH / INCHES/SEC	NUMBER OPERATING / TOTAL TAPE UNITS		
624 / …UBROUTINE	INA	INA	CORE	512	8192	512	INA	INA	WORD	TAPE READER	ELLIOTT	800 FPS	1-6	ITT K25	20,000	200 / 100	1 / 64	UP TO 8 BLOCKS OF CORE BUFFER STORAGE WITH 32 WORDS EACH ARE AVAILABLE	STANTEC SYSTEM
										TAPE PUNCH	~~TELETYPE~~ CREED	~~50 FPS~~ 300 FPS	1-6						
										CARD READER	ELLIOTT	340 CPM	1						
			DRUM	8192	8192	—	INA	5000	WORD	CARD PUNCH	ICT	150 CPM	1	AMPEX	INA	INA	1 / 64		
										PRINTER	RANK	3000 LPM	OFF LINE						
										TELEPRINTER	CREED	10 CPS	1-2						
2080 / …UBROUTINE	64 / 36	64 / 544	MERCURY DELAY LINE	402	626	—	32	.496	WORD OR MULTI-WORD	TAPE READER	INA	850 FPS	1 (OPTIONAL)	DECCA	8000	80 / 100	1 / 8	SERIAL BINARY COMPUTER	DEUCE
										TAPE PUNCH	INA	30 FPS	1 (OPTIONAL)						
			DRUM	8192	8192	—	INA	15	32 WORDS	CARD READER	ICT	200 CPM	2						
										CARD PUNCH	ICT	100 CPM	2						
14 / 14	INA	1.5 / 5	CORE	4096	32,768	4096	MAIN STORAGE 6 μS; SPECIAL WKG STORE .5 μS READ, 1 μS WRITE	MAIN STORAGE 3 μS; SPECIAL WKG STORE .5 μS	WORD	TAPE READER	INA	1000 FPS	AS REQUIRED	ENGLISH ELECTRIC	33,333	333 / 100	8 TO 16 / 64	USE OF SPECIAL WORKING STORAGES CONCURRENT OPERATION UP TO 4 PROGRAMS RUNNING ON TIME SHARING BASIS. TIME SMOOTHING ADVANCE CONTROL.	KDF-9
										TAPE PUNCH	INA	110/300 FPS							
										CARD READER	ENGLISH ELECTRIC	400 CPM							
										CARD PUNCH	ENGLISH ELECTRIC	150 CPM							
										PRINTER	RANK	3000 LPM							
										PRINTER	ENGLISH ELECTRIC	600/300 LPM							
11,000 / …UBROUTINE	INA	INA	ELECTRO-MAGNETIC DELAY LINE	71	135	16	172	500	1 DIGIT	CARD READER	BULL	150 OR 300 CPM	1-2	BURROUGHS	21,500 DIGITS	200 / 67	1 / 8	—	GAMMA 3 ET
										CARD PUNCH	BULL	150 OR 300 CPM	1-2						
			DRUM	4096	16,384	4096	72	10,000	16 WORDS	PRINTER	BULL	150 OR 300 LPM	1-2						
250 / INA	INA	INA	CORE	8192	32,768	4096	10	[illegible]	WORD	TAPE READER	BULL	300 FPS	INA	BURROUGHS	21,500 DIGITS	200 / 67	10 / 48	—	GAMMA 60
										TAPE PUNCH	BULL	25 FPS							
										CARD READER	BULL	300 CPM							
			DRUM	25,600	NO LIMIT	25,600	00	0,000	WORD	CARD PUNCH	BULL	300 CPM							
										PRINTER	BULL	300 LPM							
640 / 5120	INA	320 / 5120	CORE	1024	16,384	1024	320	6	WORD	TAPE READER	FERRANTI	200 OR 400 FPS	2	POTTER	8000	140 / 60	1 / 10	—	CAB 3030
										TAPE PUNCH	S E A	45 FPS	2						
			DRUM	16,384	16,384	—	320	20,000	32 OR 128 WORDS	PRINTER	SHEPARD	300 LPM	1						
										MICROFILM PRINTER	S E A	2000 CHAR/SEC	1						
…UBROUTINE / …UBROUTINE	INA	308 / 308	DRUM	16,384	16,384	16,384	160	[illegible]	WORD	TAPE READER	S E A	80 FPS	1 (OPTIONAL)	MAGNETIC TAPE AVAILABLE				—	CAB 500
										TAPE PUNCH	S E A	45 FPS	1 (OPTIONAL)						
			SHIFT REGISTER	16	16	16	2.5	2.5	WORD	TYPE-WRITER	FRIDEN	10 CPS	1						
5590 / …UBROUTINE …FACTORS]	48 / 48	UNDEFINED	CORE	2048 CHARACTERS	4096 CHARACTERS	—	INA	6	CHAR	TAPE READER	S E A	450 FPS	NO LIMIT	C d C (FRENCH LICENSEE OF POTTER)	3000	300 / 60	2 / NO LIMIT	DOUBLE RECORDING ON MAGNETIC TAPE	S.E.A 3900
										TAPE PUNCH	S E A	45 FPS	NO LIMIT						
			DRUM	40,960	81,920 CHARACTERS	—	INA	5,000	160 CHAR	CARD READER	ELLIOTT	400 CPM	NO LIMIT						
				CHARACTERS						PRINTER	SHEPARD	300 LPM	NO LIMIT						

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AUERBACH Electronics Corporation
Philadelphia, Pennsylvania

EUROPEAN COMPUTERS

Manufacturer and Country	Computer Name	Availability: Number On Order	Availability: Number Installed	Availability: Date of First Installation	Technique: Circuits	Technique: Clock Rate	General Machine Features: Word Length	General Machine Features: Addresses per Instruction / Instructions per Word	General Machine Features: Number of Operations Decoded / Possible	General Machine Features: Number of Index Registers	General Machine Features: Indirect Addressing	General Machine Features: Partial and Multiple Word Operations	General Machine Features: Internal Checking	Operation Times (Micro-seconds) (Including Memory Accesses): Addition (Fixed / Floating)	Operation Times: Multiply (Fixed / Floating)	Operation Times: Control Transfer (Min / Max)	Operation Times: Shift Operations (1 Place / Average)	ST: Type of Storage	ST: Number of: Minimum System	ST: Number of: Maxim[um] Syste[m]
S.E.A FRANCE	CAB 5000	INA	INA	INA	TRANSISTOR DIODE	2000 KC	42 BITS	2/1	34/INA	3	NO	DOUBLE WORD	2 PARITY BITS PER WORD	24/48	48/48	24/24	48/48	CORE DRUM	4096 16,384	32,76 131,07
S N E FRANCE	KL 901	INA	1	1960	TRANSISTOR AND VACUUM TUBE DIODE	200 KC	29 BITS	2/1	56/64	2	YES	NO	PARITY	10/20	NO OPERATION/80	10/10	10/10	CORE	1024	8192 (TOTA[L] INCLUDI[NG] FIXE[D] MEMOR[Y]
UNIVERSITY OF PISA ITALY	C E P	1	0	1960	VACUUM TUBE. GERMANIUM DIODES AND TRANSISTOR	ASYNCHRONOUS	36 BITS	1/1	512/512	64	NO	DOUBLE WORD	NO	5/100	135/135	10/24	10/52	CORE DRUM	4096 16,384	32,76 INA
OLIVETTI ITALY	ELEA 6001	4	INA	960	TRANSISTOR DIODE CORE	250 KC	VARIABLE NUMBER OF DIGITS	1-3/UNDEFINED	116/256	16	YES	DATA CONTROLLED WORD LENGTH	PARITY BIT ON EACH DIGIT	364/2198 [10 DIGIT FACTORS]	3804/3426 [10 DIGIT FACTORS]	60/60	UNDEFINED	CORE	5,000	100,00
OLIVETTI ITALY	ELEA 3003	6	1	960	TRANSISTOR DIODE	100 KC	VARIABLE NUMBER OF CHARACTERS	1/UNDEFINED	91/256	40	NO	VARIABLE WORD LENGTH CONTROLLED BY EITHER INSTRUCTIONS OR DATA	PARITY BIT ON EACH CHARACTER MODULO 3 CHECK ON ARITHMETIC	200 SUBROUTINE	1400 SUBROUTINE	100/100	UNDEFINED	CORE DRUM	20,000 0	160,00 360,0
SIEMENS AND HALSKE A G GERMANY	SIEMENS 2002	22	8	958	TRANSISTOR DIODE	200 KC	2 DECIMAL DIGITS AND SIGN	1/1	86/1000	3	YES	INA	ILLEGAL DIGIT COMBINATIONS	90/450	1260/1350	90/90	INA	CORE DRUM	1000 10,000	100,00 2,000,(CHARACT
TELEFUNKEN GERMANY	TR-4	4	0	1961	TRANSISTOR DIODE	2000 KC	48 BITS	1/2	208/256	256	YES	HALF AND DOUBLE WORD OPERATIONS	MODULO THREE CHECK ON ALL OPERATIONS	8.5/15	30/30	7.5/7.5	10.5/2	CORE FIXED CORE	8192 1024	28,6 409
STANDARD ELEKTRIK LORENZ GERMANY	ER-56	12	7	1959	TRANSISTOR DIODE	100 KC	7 DECIMAL DIGITS	1/1	82/100	9	NO	DOUBLE WORD	2 OUT OF 5 CODE	200/1000	500/1500	50/300	150/150	CORE DRUM	200 6000	300 72,0

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…PEAN COMPUTERS

…TIMES (MICRO SECONDS) …MEMORY ACCESSES)			STORAGE							ON-LINE INPUT-OUTPUT				MAGNETIC TAPE				SPECIAL FEATURES	COMPUTER NAME
…LTIPLY …IXED / …DATING	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE AVERAGE)	TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	MAXIMUM SYSTEM	MODULE SIZE	WORD TIME μSEC	ACCESS TIME μSEC	DATA UNIT ACCESSED	TYPE OF UNIT	MANUFACTURER	SPEED	NUMBER OF UNITS	MANUFACTURER	CHAR PER SECOND	BITS/INCH / INCHES/SEC	NUMBER OPERATING / TOTAL TAPE UNITS		
48/48	24/24	48/48	CORE	4096	32,768	4096	24	6	WORD	TAPE READER	SEA	400 FPS	2	C.d.C (FRENCH LICENSEE OF POTTER)	9000	300/60	2/64	SQUARE ROOT OPERATION	CAB 5000
										TAPE PUNCH	SEA	50 FPS	2						
			DRUM	16,384	131,072	16,384	160	10,000	128 WORDS	PRINTER	SHEPARD	900 LPM	1						
NO …ERATION / 80	10/10	[illegible]/10	CORE	1024	8192 (TOTAL INCLUDING FIXED MEMORY)	1024	10	5	WORD	TAPE READER	SNE	1000 FPS	1	S.N.E.	50,000 (10,000 WORDS)	200/50	2/8	SQUARE ROOT OPERATION	KL 901
										TAPE PUNCH	CREED	33 FPS	1						
135/135	10/24	[illegible]/52	CORE	4096	32,768	INA	7	3.5	WORD	TAPE READER	FERRANTI	300 FPS	2	AMPEX	20,000	270/75	1/8	FIXED FERRITE SLUG MEMORY (256 x 256 BITS) FOR CONTROL; TWO INDEX REGISTER ADDRESSES PER INSTRUCTION; EXTRA CODES	C.E.P.
										TAPE PUNCH	TELETYPE	60 FPS	3						
			DRUM	16,384	INA	16,384	39	10,000	VARIABLE	PRINTER	BULL	150 LPM	1						
3804/3426 …CTORS]	60/60	UNDEFINED	CORE	[illegible]	100,000	10,000	[illegible]	[illegible]	DIGIT	TAPE READER	OLIVETTI	800 FPS	1	AMPEX	22 500	300/75	1/6	WIRED IN MICRO SUBROUTINES AND EXPANDABLE SET OF COMMANDS	ELEA 6001
										TAPE PUNCH	OLIVETTI	50 FPS	1						
										CARD READER	BULL	150 CPM	1						
										PRINTER	OLIVETTI	600 LPM	1						
1400 / …BROUTINE	100/100	UNDEFINED	CORE	20,000	160,000	20,000	10	10	2 CHAR	TAPE READER	OLIVETTI	800 FPS	10 TOTAL	AMPEX	45,000	300/150	2/20	THREE SIMULTANEOUS PROGRAM SEQUENCES	ELEA 9003
										TAPE PUNCH	OLIVETTI	50 FPS							
										CARD READER	BULL	500 CPM							
			DRUM	[illegible]	360,000	120,000	11	[illegible]	UP TO 1920 CHAR	CARD PUNCH	BULL	150 CPM							
										PRINTER	OLIVETTI	600 LPM							
1260/1350	90/90	INA	CORE	1000	100,000	INA	4	5	WORD	TAPE READER	SIEMENS	200 FPS	1-5	SIEMENS OR AMPEX	46,000	200/120	INA/60	REAL TIME INPUT	SIEMENS 2002
										TAPE PUNCH	SIEMENS	60 FPS	1-5						
										CARD READER	IBM	800 CPM	1-5						
										CARD PUNCH	IBM	250 CPM	1-5						
			DRUM	10,000	2,000,000 CHARACTERS	[illegible]	INA	9,000	INA	PRINTER	IBM	1000 LPM	1-5						
											ANALEX	900 LPM							
30/30	7.5/7.5	0.5/2	CORE	8192	28,672	4096	6	2	WORD	TAPE READER	ELLIOTT	1000 FPS	64 TOTAL	TELEFUNKEN	37,500	375/100	8/64	OPERATIONS USUALLY FASTER THAN NOTED DUE TO OVERLAPPING MEMORY ACCESSES	TR-4
											FACIT	500 FPS							
										TAPE PUNCH	FACIT	150 FPS							
			FIXED CORE	[illegible]024	4096	256	[illegible]	1	WORD	CARD READER	IBM	800 CPM							
											BULL	300 CPM							
										CARD PUNCH	IBM / BULL	250 CPM							
500/1500	50/300	150/150	CORE	200	8000	200/1000	30	5	WORD	TAPE READER	FERRANTI	400 FPS	23 TOTAL	AMPEX	52,500 (DIGITS)	250/150	4/16	CONTROL UNIT SIMULTANEOUSLY CONNECTS ANY CORE STORAGE TO ANY INPUT, OUTPUT OR PROCESSING UNIT. TAPE BIN STORAGE UNITS	ER-56
										TAPE PUNCH	LORENZ	50 FPS							
											CREED	300 FPS							
										CARD READER	ELLIOTT	400 CPM							
			DRUM	6000	72,000	6000	INA	10,000	20-200 WORDS	CARD PUNCH	IBM	100 CPM		STANDARD ELEKTRIK	35,000 (DIGITS)	250/100	4/16		
										PRINTER	SHEPARD	900 LPM							

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AUERBACH Electronics Corporation
Philadelphia, Pennsylvania

EUROPEAN COMPUTERS

MANUFACTURER AND COUNTRY	COMPUTER NAME	AVAILABILITY: NUMBER ON ORDER	AVAILABILITY: NUMBER INSTALLED	DATE OF FIRST INSTALLATION	TECHNIQUE: CIRCUITS	TECHNIQUE: CLOCK RATE	GENERAL MACHINE FEATURES: WORD LENGTH	ADDRESSES PER INSTRUCTION / INSTRUCTIONS PER WORD	NUMBER OF OPERATIONS DECODED / POSSIBLE	NUMBER OF INDEX REGISTERS	INDIRECT ADDRESSING	PARTIAL AND MULTIPLE WORD OPERATIONS	INTERNAL CHECKING	OPERATION TIMES (MICRO-SECONDS) (INCLUDING MEMORY ACCESSES): ADDITION (FIXED / FLOATING)	MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE / AVERAGE)	STORA[GE]: TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	NUMBER OF WORDS: MAXIMUM SYSTEM
STANDARD ELEKTRIK LORENZ GERMANY	SEL-B7	1	0	INA	TRANSISTOR DIODE	100 KC	10 CHARACTERS	1 / 1	57 / 100	[illegible]	YES	PARTIAL WORD OPERATIONS	PARITY	30-180 / SUBROUTINE	SUBROUTINE / SUBROUTINE	60 / 60	INA	CORE	2000	10,000
																		DRUM	3000	80,000
ZUSE KG GERMANY	Z-22R	INA	30	1958	VACUUM TUBE	40 KC	38 BITS	1 / 1	MICRO-PROGRAMMED / 2^{18}	14	YES	DOUBLE WORD	INA	600 / SUBROUTINE	5,000 / SUBROUTINE	300	INA	DRUM	8192	8192
ZUSE KG GERMANY	Z-23	INA	0	1961	TRANSISTOR	150 KC	40 BITS	1 / 1	MICRO-PROGRAMMED / INA	240	YES	DOUBLE WORD	INA	300 / [illegible]	[illegible],000 / 10,000	300	INA	CORE	240	8431
																		DRUM	8192	8192
ZUSE KG GERMANY	Z-31	INA	0	INA	TRANSISTOR	[illegible] KC	[illegible] DECIMAL DIGITS AND SIGN	1 / 1	4[illegible] / INA		YES	DOUBLE WORD	[illegible] CODE	400 / SUBROUTINE	20,000 / SUBROUTINE	INA	INA	CORE	200	[illegible]000
N.V. ELECTROLOGICA NETHERLANDS	X 1	6	0	1958	TRANSISTOR DIODE	500 KC	27 BITS	1 / 1	48 / 64	1	NO	NO	PARITY	64 / SUBROUTINE	500 / SUBROUTINE	36 / 64	45 / 44	CORE	[illegible]	32,768
PHILIPS NETHERLANDS	PASCAL / STEVIN	1	[illegible]	1960	VACUUM TUBE TRANSISTOR DIODE	[illegible]60 KC	42 BITS	1 / 2	57 / 64	8	INA	INA	PARITY ON HALF WORD CARRY COMPARISON IN ADDER	[illegible] / [illegible]	70 / 55	4.5 / 7.5	1.5 / 42	CORE	2048	2048
																		DRUM	16384	16384
FACIT SWEDEN	EDB 1 / EDB 3	3	5	1957	VACUUM TUBE AND TRANSISTOR	80 KC	40 BITS	1 / 1	35 / 18		NO	HALF WORD OPERATIONS	NO	45 / SUBROUTINE	180 / SUBROUTINE	22 / INA	45 / 157	CORE	2048	65,536
																		DRUM	8192	8192
REGNECENTRALEN DANSK INSTITUT FOR MATEMATIKMASKINER DENMARK	GIER	1	0	1961	TRANSISTOR DIODE	500 KC	40 BITS PLUS 2 FOR WORD INDICATOR	1 / 1	37 / 64	1	YES	NO	NO	50 / INA	70 / INA	INA	INA	CORE	1024	1024
																		DRUM	12,000	12,000

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...PEAN COMPUTERS

...ON TIMES (MICRO-SECONDS) ...G MEMORY ACCESSES): MULTIPLY (FIXED / FLOATING)	CONTROL TRANSFER (MIN / MAX)	SHIFT OPERATIONS (1 PLACE AVERAGE)	STORAGE: TYPE OF STORAGE	NUMBER OF WORDS: MINIMUM SYSTEM	MAXIMUM SYSTEM	MODULE SIZE	WORD TIME µ SEC	ACCESS TIME µ SEC	DATA UNIT ACCESSED	ON-LINE INPUT-OUTPUT: TYPE OF UNIT	MANUFACTURER	SPEED	NUMBER OF UNITS	MAGNETIC TAPE: MANUFACTURER	CHAR PER SECOND	BITS/INCH / INCHES/SEC	NUMBER OPERATING / TOTAL TAPE UNITS	SPECIAL FEATURES	COMPUTER NAME
SUBROUTINE / SUBROUTINE	40 / 60	INA	CORE DRUM	2000 5000	10,000 50,000	[illegible] 3000	[illegible] INA	3 5,000	WORD WORD	TAPE READER TAPE PUNCH PRINTER	LORENZ / FERRANTI LORENZ SHEPARD	100 FPS / 300 FPS 50 FPS 300 LPM	6 6 2	STANDARD ELEKTRIK	15,000	250 / 60	24 / 48	RESERVATION SYSTEM COMPUTER WITH REAL TIME INPUT-OUTPUT FACILITIES AND LARGE BACK UP MEMORY USING TAPE BINS AND DRUMS WITH INDEPENDENT SEARCHING FACILITIES	SEL-B7
15,000 SUBROUTINE	300	INA	DRUM	8192	8192	—	300	[illegible]	WORD	TAPE READER TAPE PUNCH TYPEWRITER	FERRANTI CREED SIEMENS	200 FPS 25 FPS 10 CPS	1 1 (OPTIONAL) 1	NO MAGNETIC TAPE				—	Z-22R
13,000 / 20,000	300	INA	CORE DRUM	240 8192	[illegible] 8192	256 —	300 300	INA 5000	WORD WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	FERRANTI CREED INA INA MAUL	300 FPS 50 FPS 300 CPM 150 CPM 80 CPS	1 1 INA INA 1	INA				—	Z-23
20,000 SUBROUTINE	INA	INA	CORE	200	[illegible]	INA	300	INA	WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	FERRANTI CREED INA INA MAUL	300 FPS 50 FPS INA INA 40 CPS	INA	INA				—	Z-31
500 SUBROUTINE	36 / 64	45 / 44	CORE	[illegible]	32,768	[illegible]	32	INA	WORD	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	FERRANTI CREED BULL BULL INA	50 FPS 25 FPS [illegible] CPM [illegible] CPM 150/600 LPM	1+ 1+ 1+ 1+ 1+	INA	30,000	200 / 50	2 / 16	WIRED CORE MEMORY FOR SUBROUTINES ADDED IN 64 WORD UNITS. EACH 4096 WORD MEMORY UNIT HAS INDEPENDENT INPUT-OUTPUT CONNECTIONS	X 1
70 / 85	4.5 / 7.5	15 / 42	CORE DRUM	2048 16384	2048 16384	1024 —	[illegible] [illegible] FOR BLOCK	5 5	WORD 16 WORDS	TAPE READER TAPE PUNCH CARD READER CARD PUNCH PRINTER	PHILIPS LAB TELETYPE BULL BULL BULL	1000 FPS 60 FPS 50/750 CPM 75/150 CPM 150 LPM	1 1 1 1 1	AMPEX	45,000	300 / 150	2 / 16	30 INTERPRETIVE SINGLE ADDRESS INSTRUCTIONS IMITATING SUBROUTINES	PASCAL STEVIN
130 SUBROUTINE	22 / INA	45 / 157	CORE DRUM	[illegible] 8192	[illegible] 8192	[illegible] —	 [illegible]	1 5000	WORD 32 WORDS	TAPE READER TAPE PUNCH CARD READER CARD PUNCH	FACIT FACIT INA INA	500 FPS 50 FPS 700 CPM [illegible] CPM	8 8 8 8	FACIT	40,000	200 / 200	17 / 64	"CAROUSEL" MAGNETIC TAPE MEMORY	EDB 2 EDB 3
70 / INA	INA	INA	CORE DRUM	1024 12,000	1024 12,000	— —	3 500	4 500 BLOCK ACCESS	WORD 40 WORDS	TAPE READER TAPE PUNCH TYPEWRITER	FACIT FACIT FRIDEN	500 FPS 50 FPS 10 CPS	1 1 1	NO MAGNETIC TAPE				THE OPERATION TIMES INCLUDE INDEXING AND COUNTING. EVERY OPERATION MAY BE CONDITIONAL	GIER

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